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Fissile Materials Disposition Program

Alternative Technical Summary Report for Direct Disposition in Deep Boreholes

Direct Disposal of Plutonium Metal/Plutonium Dioxide in Compound Canisters

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Prepared by
Ananda M. Wijesinghe et al.

Lawrence Livermore National Laboratory
Livermore, CA 94551

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In Support of the
Fissile Materials Disposition Program

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CONTRIBUTORS

The following individuals contributed to the preparation of this Alternative Technical Summary Report for Deep Borehole Disposition:

1. Deep Borehole Disposition Alternative Team Leader:
   William G. Halsey, *LLNL*

2. Lead Author and Scientific Editor:
   Ananda M. Wijesinghe, *LLNL*

3. Contributing Authors:
   Guy A. Armantrout, *LLNL*
   Winslow G. Brough, *LLNL*
   Mark C. Bronson, *LLNL*
   Julio C. Diaz, *LLNL*
   Matthew J. Fischer, *LLNL*
   Darrla Giersch, *SNL*
   Patrick Gildea, *SNL*
   William G. Halsey, *LLNL*
   Tehmau Kan, *LLNL*
   Lonnie R. Moore, *LLNL*
   Richard Morley, *LANL*
   Booth R. Myers, *LLNL*
   Chan Pang, *Bechtel*
   Edward W. Russell, *LLNL*
   Ronald J. Shaffer, *LLNL*
   Henry F. Shaw, *LLNL*
   Jay Spingarn, *SNL*
   Ananda M. Wijesinghe, *LLNL*

4. Computer-Aided Graphics:
   Joel A. Watkins, *LLNL*

5. Administrative Support:
   Susan Uhlhorn, *LLNL*

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EXECUTIVE SUMMARY

This Executive Summary summarizes and compares the Immobilized and Direct Deep Borehole Disposition Alternatives presented in the alternative technical summary reports UCRL-LR-121736 and UCRL-LR-121737 by *Wijesinghe et al. (July 25, 1996a,b).* The important design concepts, facility features and operational procedures are first briefly described. This is followed by a discussion of the issues that affect the evaluation of each alternative against the programmatic assessment criteria that have been established for selecting the preferred alternatives for plutonium disposition.

ES.1 OVERVIEW OF DEEP BOREHOLE DISPOSITION ALTERNATIVES

In the deep borehole concept for geologic disposal of surplus weapons-usable fissile materials, the material will be emplaced in the lower part of one or more deep boreholes drilled in tectonically, hydrologically, thermally and geochemically stable rock formations (see Figure ES.1-1). In the current borehole disposition concept, the depths at which the fissile materials are emplaced (i.e., the 'emplacement zone') lie 2-4 km below the surface. Once the disposal form is emplaced and sealed in the emplacement zone, the 'isolation zone,' which extends from the top of the emplacement zone to the ground surface, is filled and sealed with appropriate materials. At emplacement depths, which are several thousands of meters greater than those of mined geologic repositories, the groundwater is expected to be relatively stagnant and to exist at temperatures of 75-150^{O}C, pressures of 50-100 MPa (7,500-15,000 psi) and to have salinities of up to 40% by weight. Because of the large barrier to transport posed by the isolation zone, the siting of the facility at a carefully selected stable location with stagnant groundwater at depth, and the stability and low-solubility of the disposal form the disposed material is expected to remain, for all practical purposes, permanently isolated from the biosphere.

The disposal of plutonium in deep boreholes requires the original feed materials to be first converted to a form that is suitable for emplacement in the borehole. The desired characteristics of the output disposal form include solidity, high resistance to dissolution by subsurface brines, and thermal and compositional stability over very long periods of time under the conditions that prevail at emplacement depths. In the Direct Deep Borehole Disposition Alternative, some of the original feed material forms have to be first converted to plutonium dioxide while the remaining feed types are repacked in containers without conversion. The conversion and packaging process is performed in a Disassembly & Conversion Facility which receives the feed material as plutonium pits, clean plutonum metal, clean oxide, various salts, metal scrap, sand, slag and crucibles, etc. The Facility produces, without further concentration or purification, plutonium dioxide admixtures and/or plutonium metal as the output product. This product is first packed in metal cans with double containment, then sealed in transportation containers and is delivered by SSTs to the Deep Borehole Disposal Facility. At the Deep Borehole Disposal Facility, the transportation containers are directly encapsulated in large emplacement canisters without reopening. The emplacement canisters are then lowered into the borehole and are sealed in place. Finally, the isolation zone is sealed from the top of the emplacement zone to the surface. A total of 4 deep boreholes are required.

In the Immobilized Deep Borehole Disposition Alternative, all feed forms are first converted to plutonium dioxide in a disassembly & conversion process that is similar to that used in the Direct Deep Borehole Disposition Alternative. Subsequently, the plutonium dioxide is immobilized in a ceramic matrix and is formed into ceramic-coated plutonium-loaded ceramic pellets with 1% plutonium by weight. These operations are performed in a combined Disassembly, Conversion & Immobilization Facility. The ceramic pellets are then transported by SSTs to the Deep Borehole Disposal Facility. Here the plutonium-loaded ceramic pellets are uniformly mixed with an equal volume of plutonium-free ceramic pellets (to yield a pellet mixture with an average plutonium loading of 0.5%) and a specially formulated 'grout.' The dilution of the plutonium-loaded pellets with plutonium-free pellets increases the criticality safety margin while halving the total cost of manufacturing the plutonium-loaded ceramic pellets. The mix is then directly emplaced in the uncased emplacement zone of the borehole where it sets and hardens into a concrete-like solid. No metal canisters, packaging materials or borehole casings are left in the emplacement zone of the borehole. Finally, as in the case of Direct Disposition, the isolation zone of the borehole is sealed from the top of the emplacement zone to the surface. As in Direct Disposition, a total of 4 deep boreholes are required.

The Preferred Deep Borehole Disposal Alternative

The Immobilized Deep Borehole Disposition Alternative described above is expected to perform significantly better than the Direct Deep Borehole Disposition Alternative with respect to criticality safety, post-closure isolation from the biosphere and proliferation resistance of the emplaced fissile materials. Furthermore, except for increased cost, there are no negative impacts on pre-closure ES&H, timeliness, technical maturity and other assessment criteria that significantly detract from the greater confidence it provides with regard to post-closure performance, ES&H and S&S. The immobilized deep borehole disposition alternative costs 990 $M (38.3%) more than the direct deep borehole disposition alternative. Because the benefits of superior performance of immobilized deep borehole disposition alternative are expected to more than offset its increased cost, the Deep Borehole Disposition Alternative Team recommends this design based on the *Immobilized Disposal of Plutonium in Coated Ceramic Pellets in Grout Without Canisters* as the preferred alternative for the deep borehole disposition of weapons-usable plutonium.

ES.2 DEEP BOREHOLE DISPOSITION ALTERNATIVE FACILITY DESCRIPTIONS

As shown in Figure ES.1-1, the Direct and Immobilized Deep Borehole Disposition Alternatives have key external process interfaces to Feed Source Sites, and internal process interfaces between the 'Front-End' Disassembly & Conversion/

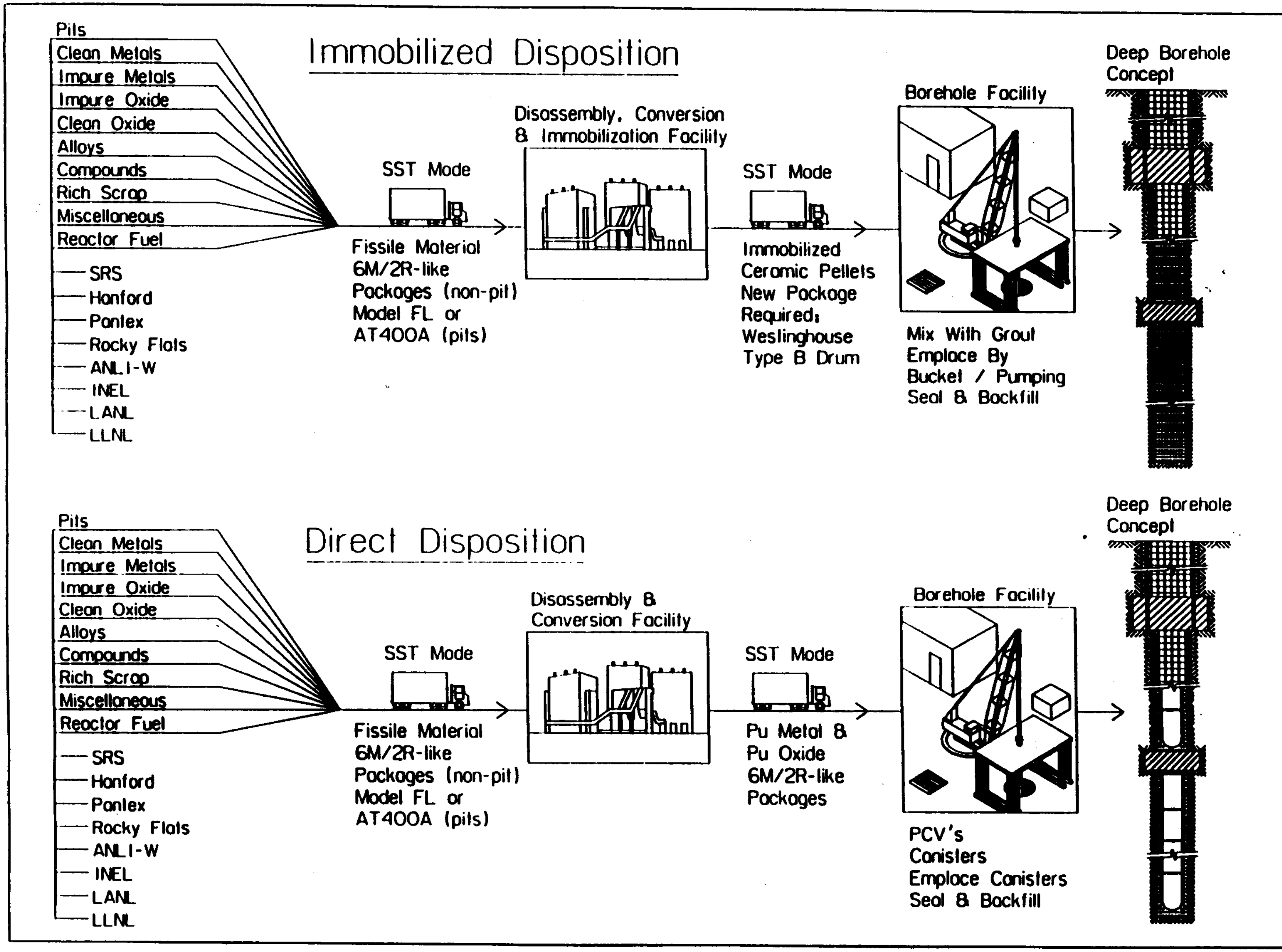


Figure ES.1-1: The End-to-End Process Flow Diagram For the Direct and Immobilized Deep Borehole Disposition Alternatives

Disassembly, Conversion & Immobilization Facility, the 'Back-End' Deep Borehole Disposal Facility, the Transportation Task, and the Safeguards and Security Task.

Surplus plutonium from various source facilities is transported to the Front-End Facility for conversion to plutonium metal or oxide in Direct Disposition, or for conversion to plutonium oxide followed by immobilization of the oxide in ceramic-coated ceramic pellets in Immobilized Disposition. Depending on their chemical compositions and physical attributes, the different feed forms to the Front-End Facility are processed differently before being transported to the Deep Borehole Disposal Facility.

The Deep Borehole Disposal Facility consists of sub-facilities for receiving and storing the disposal form, processing the disposal form, and emplacing the disposal form in the boreholes. In the Direct Disposition Alternative, the plutonium metal and plutonium oxide feed are delivered in sealed 6M/2R-like canisters. These are further encapsulated in emplacement canisters at the Deep Borehole Disposal Facility. The emplacement canisters are lowered into the boreholes and are grouted in place. In the Immobilized Disposition Alternative, the plutonium loaded ceramic pellets are delivered in a Type B double containment drum package (the proposed package is the new Westinghouse Type B 208-liter (55-gal) drum package that is currently under development). The ceramic pellets, which are stored on-site until needed, are then transported to the emplacing facility where the plutonium loaded pellets are mixed with grout and an equal volume of plutonium-free filler ceramic pellets. The resulting slurry is emplaced within the boreholes either by bucket or by pneumatically pumping the wet slurry into the borehole through a delivery pipe. Finally, when plutonium is emplaced along the entire 2 km length of the emplacement zone in the lower half of the borehole, the remainder of the borehole is filled and sealed with appropriate materials.

ES.3 ASSESSMENT AGAINST EVALUATION CRITERIA

ES.3.1 Criterion 1: Resistance to Theft or Diversion By Unauthorized Parties

Safeguards and security systems are established to preclude theft and diversion of the attractive fissile materials in the Deep Borehole Disposition Alternatives. The Front-End Facility (i.e., the Disassembly & Conversion Facility or the Disassembly, Conversion & Immobilization Facility) and the Deep Borehole Disposal Facility will be secure nuclear facilities while the transportation of plutonium exposes the materials to increased threats of theft and diversion. After emplacement and sealing of the borehole, the intrinsic (self) protection of the geologic barrier is very significant.

The proliferation risks of the Direct and Immobilized Deep Borehole Disposition Alternatives can be analyzed in terms of the *Environment*, *Material Form* and *S&S Assurance* measures. This assessment is assessed through qualitative measures in Table ES.3.1-1 and is summarized below:

- ***Direct Disposal Alternative:*** The plutonium is received at the Disassembly & Conversion Facility as a highly attractive material and it remains so until it is encapsulated in large canisters at the Deep Borehole Disposal Facility. When encapsulated, although the material form of the plutonium is still attractive, the proliferation risk is reduced as a result of the large size and weight of the emplacement canisters. The Disassembly & Conversion Facility and the Deep Borehole Disposal Facility will be secure nuclear facilities. In addition, the transportation of plutonium exposes the materials to threats of theft and diversion. *The 'stored weapon standard' will be maintained to the extent practical consistent with DOE requirements.* After emplacement and sealing of the borehole, the intrinsic

Table ES.3.1-1: Potential Risks for Threats and Criteria 1 & 2 for Deep Borehole Disposition Alternatives

	Inter-Site Transport	Disassembly Conversion	Immob. Process	Inter-Site Transport	Borehole Facility	Borehole Disposed
DIRECT DISPOSITION						
Threat						
Covert Threat	Medium	High		Medium	Medium	Low
Overt Threat	Medium	Medium		Medium	Medium	Low
Diversion	Medium	High		Medium	Medium	Low
Criterion 1						
Material Form	High	High		High	Medium	Low
Environment	Medium	Medium		Medium	Medium	Low
Safeguards and Security	Medium	High		Medium	Medium	Low
Criterion 2						
Detectability	High	High		High	Medium	Low
Irreversibility	High	High		High	Medium	Low
IMMOBILIZED DISPOSITION						
Threat						
Covert Threat	Medium	High	High/Med.	Medium	Low	Very Low
Overt Threat	Medium	Medium	Medium	Medium	Low	Very Low
Diversion	Medium	High	High/Med.	Medium	Low	Very Low
Criterion 1						
Material Form	High	High	High/Med.	Medium	Low	Very Low
Environment	Medium	Medium	Medium	Medium	Low	Very Low
Safeguards and Security	Medium	High	High/Med.	Medium	Low	Very Low
Criterion 2						
Detectability	High	High	High/Med.	Medium	Medium	Very Low
Irreversibility	High	High	High/Med	Medium	Medium	Very Low

(self) protection of the geologic barrier is very significant *so that the 'spent fuel standard' is achieved and maintained following the emplacement of the canisters in the borehole*. Post-closure monitoring, for example by satellites in earth orbit, will contribute to the proliferation resistance of the Direct Deep Borehole Disposition Alternative.

- ***Immobilized Disposal Alternative:*** The plutonium is received at the Disassembly, Conversion & Immobilization Facility as a highly attractive material. Once the material is processed, blended and converted to ceramic, the material form is much less attractive. Also, because the concentration of plutonium in the ceramic pellets is very low, a large quantity of pellets is required to produce a 'significant quantity.' Although the pellets are processed in bulk, they are subsequently handled in drummed packages subject to itemized accounting. Prior to emplacement in the borehole, the material does not meet the spent fuel standard and requires appropriate safeguards. *Therefore, the 'stored weapon standard' will be maintained to the extent practical consistent with DOE requirements.* After emplacement and sealing in the borehole, *the final disposition environment, form and S&S assurance for the Immobilized Deep Borehole Disposition Alternative meets or exceeds the spent fuel standard.* Post-closure monitoring, for example by satellites in earth orbit, will contribute to the proliferation resistance of the Immobilized Deep Borehole Disposition Alternative.

ES.3.2 Criterion 2: Resistance to Retrieval, Extraction, and Reuse by Host Nation

The primary barriers to retrieval and reuse include the IAEA's independent verification procedures, the difficulty of completing the task undetected by IAEA representatives, and the significant task time. Given the substantial post-emplacement proliferation resistance inherent in the Deep Borehole Disposition Alternative (i.e., the difficulty of retrieving the material following emplacement), the materials involved are only considered credible targets prior to emplacement.

The IAEA has established a set of 'Safeguards Criteria' for the MC&A, and the C/S of fissile material. The requirements in this area are derived from IAEA Statutes and Informational Circulars. The IAEA safeguards criteria and security recommendations are typically based on practices followed in the U.S.A. and agreed upon by the IAEA member states. The International Diversion, Retrieval, Extraction, and Reuse criterion (Criterion 2) evaluates the system resistance to diversion of material before final disposition by the weapon state itself, retrieval of material after final disposition by the weapon state itself, and conversion of the material back into weapon usable form *covertly* by the host nation/state. The IAEA does perform independent verification of the data from the state's system of material control and accounting. The IAEA, in performing its safeguards inspection activities, audits the facility records and makes independent measurements of selected samples of each kind of nuclear material in the facility. There is an inherent limitation on the accuracy of NDA measurements that presents an increased risk of diversion at high throughput facilities. This is where C/S plays an important role in assuring material accountability. The primary safeguards against these risks are the irreversibility of the material forms (e.g., the difficulty of converting the material into a weapons-usable form) and the ability to detect diversion, retrieval and conversion. This assessment is assessed through qualitative measures in Table ES.3.1-1 and is summarized below:

- ***Direct Disposal Alternative:*** *The final disposition form, environment, and S&S for this alternative meets the spent fuel standard.* Prior to borehole disposition the material does not meet the spent fuel standard and therefore protection commensurate with its attractiveness level must be provided. The protection offered by the Direct Deep Borehole Disposal Alternative is less than that of the Immobilized Deep Borehole Disposition Alternative in the steps following Disassembly & Conversion up to and including final disposition.

- ***Immobilized Disposal Alternative:*** *The final disposition form, environment, and S&S for this alternative meets the spent fuel standard.* Prior to borehole disposition the material does not meet the spent fuel standard and therefore protection commensurate with its attractiveness level must be provided. The protection offered by the Immobilized Deep Borehole Disposal Alternative is greater than that of the Direct Disposition Alternative in the steps following Immobilization up to and including final disposition.

ES.3.3 Criterion 3: Technical Viability

ES.3.3.1 Technical Maturity

While no deep borehole disposal facilities for plutonium disposition have ever been developed, many of the technologies needed for this alternative are quite mature, and the basic concept has been considered previously. The overall concept of deep borehole disposition has been considered in recent decades for disposal of both hazardous and radioactive wastes. This concept received significant investigation in the 1970s for disposal of high-level radioactive waste (HLW) and spent nuclear reactor fuel (SNF). Similar studies have been conducted in other countries including Russia, Sweden and Belgium.

The front end technologies for processing and converting the various potential Pu feed forms are similar to, or less demanding than, those for all other disposition alternatives. Transportation, MC&A and Safeguards technologies have been demonstrated, although continued improvements may be desirable. Fissile material containing ceramic pellet production is a mature technology for nuclear fuel production and has been used for Pu containing MOX fuel. The pellet coating process is also a mature technology that is, for example, also being considered for the High Temperature Gas Reactor fuel. The borehole drilling, emplacement and sealing technology is available as an extrapolation from large hole techniques for nuclear weapons testing and deep drilling for resource exploration and geotechnical research.

The technical maturity of the Immobilized and Direct Deep Borehole Disposition Alternatives were evaluated by first decomposing the unit processing operations of each alternative according to the second-level processing flow diagrams and assigning an unweighted technical maturity level to each unit operation according to a 12-level maturity scale. The 12-level maturity scale was graded from the conceptual stage (level 1), laboratory feasibility testing (levels 2-4), prototype testing (5-10) to commercialization (levels 11-12). Relative importance weights, graded on 3-level scale (0.1, 1, 10), were then applied to weight the technical maturity of each unit operation according to its importance to the viability of the alternative as a whole. The dependence of the technical viability of the two disposition alternatives on post-closure ES&H performance (i.e., isolation of the disposed plutonium from the biosphere and criticality safety) was taken into account separately from the process of disposing of the plutonium. The pre-closure disposition operations and the post-closure performance were assigned relative importance weights of 0.75 and 0.25, respectively. Two weighted technical maturity measures (0-1 scale and 0-12 scale) were computed from the weighted average of the technical maturities of the individual operating units for each surface facility and the post-closure ES&H performance for each deep borehole disposition alternative. These results are summarized in Table ES.3.3.1-1. The details of the procedure used to compute these values are given in the main text of the two reports. From Table ES.3.3.1-1 it can be seen that the overall technical viabilities of the Immobilized and Direct Disposition Alternatives are very nearly the same. It can also be

Table ES.3.3.1-1: Weighted Technical Maturity of Deep Borehole Disposition Alternatives

Facilities & Alternatives	Technical Maturity (0-1 Scale)	Technical Maturity (0-12 Scale)
IMMOBILIZED DISPOSITION		
Disassembly & Conversion Sub-Facility	0.78	9.4
Immobilization Sub-Facility	0.68	8.2
Disassembly, Conv. & Immobilization Facility	**0.71**	**8.5**
Deep Borehole Disposal Facility	**0.69**	**8.3**
Post-Closure ES&H Performance	**0.67**	**8.0**
Immobilized Disposition -25% post-closure weight	***0.69***	***8.3***
Immobilized Disposition -75% post-closure weight	***0.68***	***8.1***
DIRECT DISPOSITION		
Disassembly & Conversion Facility	**0.82**	**9.8**
Deep Borehole Disposal Facility	**0.76**	**9.1**
Post-Closure ES&H Performance	**0.50**	**6.0**
Direct Disposition - 25% post-closure weight	***0.70***	***8.4***
Direct Disposition - 75% post-closure weight	***0.57***	***6.8***

seen that while the pre-closure operations of the simpler Direct Disposition Alternative are more technically mature, the Immobilized Disposition Alternative is more technically viable than Direct Disposition with respect to post-closure ES&H performance. In this context, in deep borehole disposition the spent fuel standard is achieved upon emplacement of the disposal form within the borehole rather than during the processing operations at the surface. Therefore, we believe that in the assessment of technical viability the weighting of the pre-closure to post-closure weighting of 75%:25% should be changed to 25%:75% in favor of post-closure performance. The results for 75%

weighting of post-closure performance given in Table ES.3.3.1-1 show that the impact of weighting post-closure performance more heavily is to decrease the technical viability of the direct disposition alternative relative to the immobilized disposition alternative. This reflects more appropriately the increase in performance gained as a result of immobilizing the plutonium at extra effort and cost.

ES.3.3.2 Technical Unknowns & Risks

Technical unknowns for deep borehole disposition center around underground conditions and processes that affect post-closure performance. It is believed that suitable rock formations can be found in a variety of areas and that they can be adequately characterized, and the long term evolution of processes predicted, to provide sufficient assurance of long term isolation and safety. However, this has not been demonstrated, and will not be demonstrated until implementation of this concept.

The immobilized deep borehole disposition alternative differs somewhat from the direct deep borehole disposition alternative in the area of technical unknowns. The extra cost of immobilizing the plutonium is accepted in part to give added assurance of long term isolation safety and a simplified licensing safety argument. Thus, this alternative is lower in technical uncertainty than the direct deep borehole disposition alternative.

The reasons for this increased confidence in the immobilized deep borehole disposition alternative with respect to long-term performance are:

1. Reduced Post-Closure Contaminant Mobilization: The ceramic pellet disposal form used in the immobilized disposal alternative is the highest performing, most geologically compatible and thermodynamically stable disposal form that is available. The solubilty and Pu-release from this disposal form is at least 3-4 orders of magnitude lower than those of other competing disposal forms including the Pu/PuO_2 disposal form of the direct disposal alternative. The ceramic pellet design has an additional advantage derived from small pellet size: the resistance of the pellets to fracture and further increase in the surface area exposed to dissolution. This advantage is not enjoyed by disposal forms of large size that are susceptible to fracture both during the process of fabrication and under disruptive mechanical and chemical processes after emplacement.

2. Increased Confidence in Emplacement Zone Sealing: The degree of isolation of the disposed plutonium from the biosphere will depend not only on the geologic barrier posed by the geosphere, but also on the nature of the transport mechanisms and the resistance to transport up the borehole offered by the borehole seals. It is necessary to seal adequately not only the isolation zone in the upper half the borehole but also the emplacement zone in the bottom half of the borehole. In design concepts that employ emplacement canisters, borehole sealing may be compromised as a result of corrosion induced disintegration (in about 100 years) or earthquake induced disruption of the canisters that could increase the hydraulic conductivity of the seals. As a result, fluid flow and convective transport of the fissile material towards the biosphere along the borehole may be increased. This possibility may not be mitigated by the presumed lack of forces driving fluid flows at emplacement depths, and the large barrier offered by the isolation zone, because it is known that conductive fractures persist to great depths and that the lack of fluid flow at great depth now does not preclude it from occurring in the future. For example, pressurization of brine in deep geological formations by earthquakes can cause fluid migration towards low pressure zones that persist over hundreds of thousands of years - time enough to dissolve and mobilize Pu from the disposal forms. Furthermore, no region is free of deep penetrating fractures, it is only a matter of to what degree it is fractured and to what extent it is tectonically stable. Fractures that intersect the emplacement zone may short circuit the isolation zone. Consequently, the emplacement zone must also be sealed adequately to minimize this possibility.

3. Increased Post-Closure Criticality Safety: The plutonium loading in the ceramic pellet option has been kept to a very low 0.5% effective loading (for a 1:1 mix of 1% plutonium-loaded pellets and plutonium-free pellets). This drives the criticality coefficient down to a value of 0.67 under the worst possible brine saturated conditions *without the addition of any neutron absorbers*. This is far below the value of 0.95 specified for the safe storage of plutonium metal in surface facilities. In this design, our calculations show that there is no combination of size, shape or water/brine saturation of a region occupied by the disposal form that would drive the system to criticality. Increase in halide salt concentration in the brine, or reduction in the degree of water saturation, only increases the margin of safety. The only possible, but highly unlikely, post-closure scenario for criticality is that in which, over a very long period, the Pu is dissolved out from the ceramic, and is transported to a location where it either precipitates out or is sorbed on rock as a mineral assemblage in sufficient quantities to form a critical mass. Because the Pu-concentration in the precipitate would be very small, and the pore spaces available to accomodate precipitated material in fractured and unfractured rock at depth are very small, this is very unlikely. This, however, does not preclude it from happening in a sufficiently large cavity over a very long period of time. Criticality of the very long lived ^{235}U (a decay product of the much shorted lived ^{239}Pu) can be prevented by incorporating depleted $^{238}UO_2$ in the ceramic pellets. The ^{235}U would then transport and chemically combine in the same way as the ^{238}U but because of isotopic dilution would not become critical. Furthermore, because the chemical behavior of plutonium and uranium are very similar, ^{239}Pu and ^{238}U are also likely to transport without separation, thus providing a measure of criticality safety for the dissolved Pu before the Pu has decayed to ^{235}U. On the other hand, no assurance can be given that the physical separation of the Pu/PuO_2 in the emplacement canisters in the direct disposition alternative would not be reduced by a physically disruptive event, by selective erosion and removal of the sealant, or by selective plastic flow and extrusion of the sealant after disintegration of the canister. In that event, even the close juxtapositioning of as few as three product cans could result in a criticality event. Many arguments can be given to show that this is unlikely to occur, but not with sufficient power to convince and prevent a controversy that could compromise licensing of the direct deep borehole disposition alternative.

4. Reduced Post-Closure Safeguards & Security Risks*:* The retrievability of the emplaced plutonium from the borehole is a much more costly and time consuming task for the immobilized alternative because of the low plutonium concentration in the ceramic pellets (0.5% average) and the resulting large mass that must be retrieved. On the other hand, although both deep borehole disposition alternatives require redrilling through the 2 km deep isolation zone, it is much easier to selectively locate and extract the small product cans/primary containment vessels in the direct disposition alternative if the emplacement canisters and inner primary containment vessels have not yet disintegrated. Even after disintegration of the canisters it is much easier to remotely detect and extract the highly concentrated plutonium from the former locations of the disintegrated small product cans. After retrieval from the borehole, the immobilized material will require much more processing to recover weapons-grade plutonium than the simple density based processes (e.g., sedimentation) required to separate high grade Pu from the waste materials recovered from the borehole in the direct deep borehole disposition alternative.

ES.3.3.3 Regulatory/Licensing Requirements

Regulatory uncertainty is the largest single uncertainty that affects the viability of deep borehole disposition. A regulatory plan for interacting with potential regulators is being followed to develop mutually acceptable agreements and regulatory solutions early to reduce this uncertainty. Preliminary discussions with licensing experts indicate that solutions can indeed be developed given sufficient time, or a social and congressional mandate. Certain of these issues are qualitatively similar for both Direct and Immobilized Deep Borehole Disposition Alternatives.

Concentrated, separated, fissile material in significant quantities has never been considered for direct disposition before and many current waste management regulations are not clearly appropriate for such a facility. This uncertainty, however, is greater for the Direct Deep Borehole Disposition Alternative than the Immobilized Deep Borehole Disposition Alternative in which the fissile material concentration is very low. This implies a need for a new category or sub-category of waste for excess weapons-usable fissile material and federal legislation to specify regulatory jurisdiction over any disposition activities. Because concentrated plutonium has never been considered waste and does not conform to the definition or the acceptance criteria for any waste form that is currently regulated, it is expected that specific legislative and regulatory action will be needed to guide fissile material disposition. Licensing requirements are a key area in which there are no clearly applicable regulations for the deep borehole disposition. Concentrated plutonium disposition forms meet neither the requirements for HLW nor the normal criteria for TRU. However, the HLW repository and WIPP provide useful precedents that governing legislation and regulations for licensing a plutonium disposition facility can and should be specifically developed.

Siting guidelines are another area of uncertainty. Site suitability guidelines such as those of 10 CFR 960 for the HLW repository program were developed specifically for a mined geologic repository that permits human access for characterization, and for a facility for isolation of material that poses a much greater potential dose hazard than the excess fissile material and which must satisfy specific system and subsystem performance requirements. Many of the provisions of Part 960 are clearly not appropriate for the deep borehole disposal facility. A current activity in the FMDP deep borehole disposition task is to consider potential site characteristics and the beneficial and adverse impacts that could result from these characteristics. The results from these preliminary studies should provide a basis for defining site guidelines in the future.

ES.3.4 Criterion 4: Environmental, Safety & Health Compliance

ES&H compliance of deep borehole disposition alternatives need to be assessed by considering the impacts and consequences of constructing and operating all of the facilities in the end-to-end alternative during the pre-closure and post-closure phases. These impacts include the wastes and emissions generated during construction and normal operation, the contaminant releases and other risks associated with design-basis and beyond-design-basis accidents, the possibility of long-term contaminant release from the emplaced disposal form to the biosphere, and the criticality safety of the plutonium emplaced in the borehole. All operations of both deep borehole alternatives will be carried out safely in compliance with existing ES&H standards. Generally, the wastes and emissions generated by the immobilized deep borehole disposition alternative during the processing operations at the surface are somewhat greater than those of the direct deep borehole disposition alternative because of the additional immobilization step in the former alternative. The long-term performance and safety of the immobilized deep borehole alternative, however, significantly exceeds that of the direct deep borehole disposition alternative with respect to both the potential for contamination of the biosphere and the occurrence of any post-closure long-term criticality events. The ES&H impacts of the two alternatives are summarized below.

ES.3.4.1 Wastes & Emissions from Construction & Operations

The Hazardous, Nonhazardous and Criteria Pollutant wastes and emissions from the construction of the Front-End and Deep Borehole Disposal Facilities are comparable for the Immobilized and Direct Disposition alternatives. The wastes and emissions of concern that are generated during operation of these Facilities are Radioactive & Hazardous Wastes, Non-Hazardous Wastes, Criteria Pollutant Emissions, Radiological Emissions and Other Industrial Chemical Effluents. For the Front-End Facility, the Other Industrial Chemical Effluent (e.g., carbon dioxide, chlorine, hydrochloric acid, nitric acid) quantities are comparable for the two alternatives with the exception that a significant quantity of dissolved solids is produced by the ceramic pellet manufacturing process. The Radioactive & Hazardous wastes produced by the Facility in these two alternatives are also comparable except that about ten times as much TRU waste is produced by the immobilized alternative (168 m^3) when compared to the direct alternative (15 m^3). Significantly more Criteria Pollutant Emissions (e.g., sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds and other hydrocarbons) are produced by the immobilized disposition alternative than the direct disposition alternative. In contrast, the direct disposition alternative produces about 50 times more transuranic Radiological Emissions (500 nCi/yr) than the immobilized disposition alternative. For the Deep Borehole Facility, the wastes and emissions generated during operation are comparable for both immobilized and direct disposition alternatives in all of the categories, except in the Hazardous Waste category where about 70 times more liquid hazardous waste is generated in the immobilized disposition alternative as a result of the ceramic pellet-grout mixing and emplacement operations.

Generally, the wastes and emissions generated by the immobilized borehole disposition alternative during the processing operations at the surface are somewhat greater than those of the direct deep borehole disposition alternative because of the additional immobilization step in the former alternative. The significances of these differences in wastes and emissions from an ES&H perspective must be evaluated in the light of their probable consequences and risks. This assessment is presented in the Programmatic Environmental Impact Statement.

ES.3.4.2 Accident Scenarios & Accidental Releases

Design-basis and beyond-basis-accident scenarios have been defined and analyzed for the Front-End and Deep Borehole Disposal Facilities of both immobilization and direct disposition alternatives. The analyses provide best estimates of the accident probability, the source terms at risk, the respirable airborne fraction and the fraction of the source released as a result of each type of accident. These results are given in the corresponding Alternative Technical Summary Reports. They indicate that given the accident mitigating safety features incorporated in the facility designs, the releases comply with safety standards. More accident scenarios have been included for the Front-End Facility of the immobilized borehole disposition alternative than for the direct borehole disposition alternative because of the greater number of processing steps and their complexity, but the accident probabilities and potential releases are not significantly greater than for the direct borehole disposition alternative.

The Deep Borehole Disposal Facility operations and accident scenarios are quite different for the immobilized and direct borehole disposition alternatives due to the differences in the disposal form and the method of emplacing it in the borehole. In general, the criticality risk associated with handling and emplacing the uncanistered ceramic-pellet disposal form in the immobilized borehole disposition alternative is extremely low due to the very low Pu-loading of the ceramic pellets. In contrast, the concentrated form of the plutonium in the direct borehole disposition alternative makes safety during emplacement operations a top priority. The safety risk is reduced by maintaining the borehole full of a sufficiently viscous fluid (e.g., mud) during canister emplacement to limit the terminal velocity of a free-falling canister to below that required to rupture the canister upon impact at the bottom of the borehole. The presence of mud in the borehole, however, complicates sealing of the emplacement zone of the borehole after emplacement of each canister string. Among the safety features incorporated in the emplacement facility of both immobilized and direct borehole disposition alternatives is a containment structure that covers the entrance to the borehole at the surface to limit accidental and/or normal (for ceramic pellets) effluent releases.

ES.3.4.3 ES&H Consequences of Normal Operations & Accidents

The wastes and emissions generated by normal operation and potential accidents at the Deep Borehole Disposal Facility in each of the two alternatives were summarized in the previous sections. The consequences of these releases on safety and health of the environment and people must be evaluated to be able to assess the performance of the Deep Borehole Disposition Alternatives against the ES&H criterion. The ES&H consequences and associated risk have been evaluated for each separate facility and are given in the the report entitled *Draft Programmatic Environmental Impact Statement for Storage and Disposition of Weapons-Usable Fissile Materials (DOE/EIS-0229-D, February, 1996).*

ES.3.5 Criterion 5: Cost Effectiveness

The cost estimates for the nominal case of 10 year operation of the Front-End and Borehole Facilities are given in Table ES.3.5-1. These estimates show that the cost premium paid to immobilize the plutonium (926 $M) in addition to performing the disassembly and conversion front-end operations is double the cost of disassembly and conversion (583 $M) required for the direct disposition alternative. The total cost of the immobilized deep borehole disposition alternative (i.e., of both front- and back-ends)

Table ES.3.5-1: Cost Summary for Deep Borehole Disposition Alternatives

COST ITEM DESCRIPTION	IMMOBILIZED DISPOSITION			DIRECT DISPOSITION		
	D,C & I Facility $M	Borehole Facility $M	Immobilized Alternative $M	D&C Facility $M	Borehole Facility $M	Direct Alternative $M
Up-Front Costs	**583**	**765**	**1,348**	**244**	**865**	**1,109**
Operating Costs	**1,509**	**717**	**2,226**	**804**	**671**	**1,475**
Tot. Life Cycle Cost	**2,092**	**1,482**	**3,574**	**1,048**	**1,536**	**2,584**

exceeds that of the direct deep borehole disposition alternative by 38.3% (i.e., by 990 $M) of the cost of the direct borehole disposition alternative. However, in view of the greater confidence in long term performance and safety, the immobilized disposition alternative remains the preferred deep borehole disposition alternative.

ES.3.6 Criterion 6: Timeliness

The preliminary nominal schedule to site, license, deploy, operate, and decommission/close an integrated system for the Direct and Immobilized Deep Borehole Disposal of surplus weapons plutonium is presented in Figure ES.3.6-1.

The critical start and end dates for each alternative are summarized in Table ES.3.6-1. The schedule assumes a project start date of January 1, 1996, which is consistent with the current December 1, 1996 scheduled date for the PEIS record of decision (ROD).

Table ES.3.6-1: Timeliness Measures for Immobilized & Direct Deep Borehole Disposition Alternatives

Timeliness Measure	Years From Project Start (1/1/97)	Date
Start Emplacement	**10**	**1/1/07**
End Emplacement	**20**	**12/31/16**
Seal Last Borehole	**20.5**	**6/30/17**
Close All Sites	**22**	**12/31/18**

ES.3.6.1 Scheduling Issues

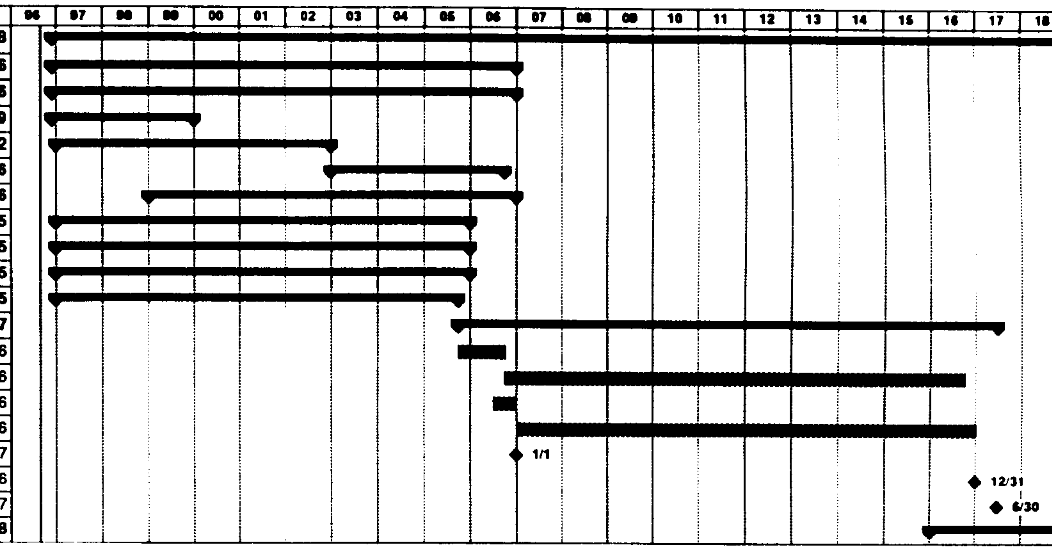
- ***Legislation and Rulemaking:*** The legislative and regulatory framework for the disposition of surplus weapons Pu is not well established at the present time. Thus, present laws and regulations will need, at the least, to be modified or amended to cover the disposal alternative.

- ***Site Selection & Characterization:*** Non-site-specific research and development and site screening activities are carried out parallel with the legislative and rulemaking period. Site characterization and determination of site suitability follow site selection and are critical path activities that culminate in the submission of a license application to the NRC.

- ***Deep Borehole Disposal Facility Licensing:*** A key program assumption is that any new facility would be licensed by the NRC. A reasonable approach to deep borehole facility licensing has been developed.

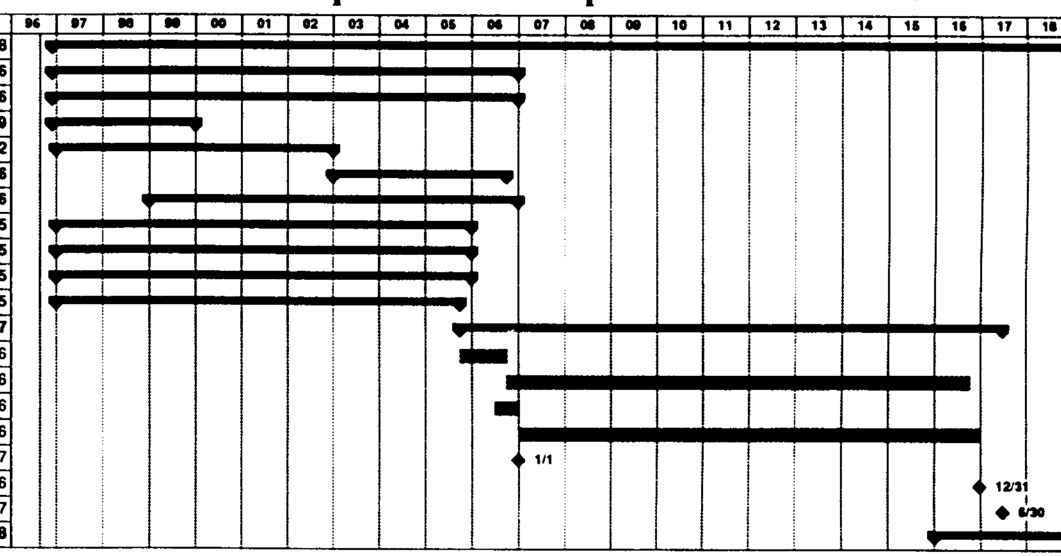
Nominal Implementation Schedule for the Immobilized Deep Borehole Disposition Alternative

ID	Task Name	Years	Start	Finish
1	TOTAL BOREHOLE LIFE CYCLE TIME	22	Sun 12/1/96	Mon 12/31/18
2	PRE-OPERATIONAL PERIOD	10	Sun 12/1/96	Sun 12/31/06
3	Deep Borehole (DBH) Facility	10	Sun 12/1/96	Sun 12/31/06
4	Legislation & Rulemaking	3.25	Sun 12/1/96	Fri 12/31/99
10	Site Selection & Characterization	6	Wed 1/1/97	Tue 12/31/02
20	Borehole NRC Licensing Proceedings	4	Wed 1/1/03	Sat 9/30/06
27	Environmental/NEPA/NRC for DBH	8	Tue 1/5/99	Sun 12/31/06
34	DBH Facility Design & Construction	9	Wed 1/1/97	Fri 12/30/05
38	Dis., Conv. & Immob. (D,C&I) Facility	9	Wed 1/1/97	Sat 12/31/05
39	Permitting/Licensing	9	Wed 1/1/97	Sat 12/31/05
45	Design & Construction	8.75	Wed 1/1/97	Fri 9/30/05
51	OPERATIONAL PERIOD	11.75	Sat 10/1/05	Fri 6/30/17
52	D,C & I Facility Cold Operations	1	Sat 10/1/05	Sat 9/30/06
53	D,C & I Facility Hot Operations	10	Mon 10/2/06	Fri 9/30/16
54	DBH Facility Cold Operations	0.5	Fri 6/30/06	Sun 12/31/06
55	DBH Facility Hot OPerations	10	Wed 1/3/07	Sat 12/31/16
56	Start Emplacement	0	Mon 1/1/07	Mon 1/1/07
57	End Emplacement	0	Sat 12/31/16	Sat 12/31/16
58	Emplacement Complete	0	Fri 6/30/17	Fri 6/30/17
59	POST-OPERATIONAL PERIOD	3	Mon 1/4/16	Mon 12/31/18



Nominal Implementation Schedule for the Direct Deep Borehole Disposition Alternative

ID	Task Name	Years	Start	Finish
1	TOTAL BOREHOLE LIFE CYCLE TIME	22	Sun 12/1/96	Mon 12/31/18
2	PRE-OPERATIONAL PERIOD	10	Sun 12/1/96	Sun 12/31/06
3	Deep Borehole (DBH) Facility	10	Sun 12/1/96	Sun 12/31/06
4	Legislation & Rulemaking	3	Sun 12/1/96	Fri 12/31/99
10	Site Selection & Characterization	6	Wed 1/1/97	Tue 12/31/02
20	Borehole NRC Licensing Proceedings	3.75	Wed 1/1/03	Sat 9/30/06
27	Environmental/NEPA/NRC for DBH	8	Tue 1/5/99	Sun 12/31/06
34	DBH Facility Design & Construction	9	Wed 1/1/97	Fri 12/30/05
38	Disassembly & Conver.(D&C) Facility	9	Wed 1/1/97	Sat 12/31/05
39	Permitting/Licensing	9	Wed 1/1/97	Sat 12/31/05
45	Design & Construction	8.75	Wed 1/1/97	Fri 9/30/05
51	OPERATIONAL PERIOD	11.75	Mon 10/3/05	Fri 6/30/17
52	D&C Facility Cold Operations	1	Mon 10/3/05	Fri 9/29/06
53	D&C Facility Hot Operations	10	Mon 10/2/06	Fri 9/30/16
54	DBH Facility Cold Operations	0.5	Fri 6/30/06	Fri 12/29/06
55	DBH Facility Hot OPerations	10	Wed 1/3/07	Fri 12/30/16
56	Start Emplacement	0	Mon 1/1/07	Mon 1/1/07
57	End Emplacement	0	Sat 12/31/16	Sat 12/31/16
58	Emplacement Complete	0	Fri 6/30/17	Fri 6/30/17
59	POST-OPERATIONAL PERIOD	3	Mon 1/4/16	Mon 12/31/18



Project: Plutonium Disposition
Date: Fri 8/23/96

Task — Progress — Milestone ◆ — Summary — Rolled Up Task — Rolled Up Milestone ◇ — Rolled Up Progress

Figure ES.3.6-1: Summary Nominal Implementation Schedules for Immobilized and Direct Deep Borehole Disposition Alternatives

- ***Environmental/NEPA for Deep Borehole Disposal Facility:*** It is assumed that a site-specific EIS will need to be prepared for the Deep Borehole Disposal Facility in parallel with site characterization and submitted to the NRC somewhat before the DOE files for the borehole license application. Following the issuance of the SER for the Deep Borehole Disposal Facility by the NRC, the NRC prepares and issues a draft EIS, which is made available for public comment.

- ***Deep Borehole Disposal Facility Design & Surface Facility Construction:*** Conceptual design of the Deep Borehole Disposal Facilities begins immediately after the ROD, and extends through site selection (4.5 years total). Once a site has been selected, Title I design begins, followed by Title II design and are completed in time for the DOE to incorporate them into the Deep Borehole Disposal Facility. Construction of the surface facilities begins after completion of Title II design.

- ***Front-End Disassembly & Conversion/Disassembly, Conversion & Immobilization Facility Licensing, Design, and Construction:*** The schedule of activities leading up to the cold startup of the Front-End Facility is on the critical path. The schedule presented for this case can be compressed but the sequence of activities leading up to the licensing of the Deep Borehole Disposal Facility must be compressed for early completion of disposition.

- ***Operational Period:*** Operations in the Front-End Facility begin as soon as construction of the facility is complete with a half-year cold operations period, followed by 10 years of hot operations in the base case corresponding to the case analyzed in the PEIS. Similarly, the Deep Borehole Disposal Facility activities begin with a half-year of cold operations, followed by 10 years of hot emplacement operations. Disassembly & Conversion/Disassembly, Conversion & Immobilization and emplacement activities are on the critical path, and there is the potential for significant time savings if an accelerated program of processing/ immobilization and emplacement is undertaken. Note that the rate of operation of the borehole itself will be feed-rate limited in the base case; any reduction in the time required to immobilize the Pu can be directly utilized to decrease the time to completion of disposition. An accelerated disposition case in which the disposition period was compressed into 3 years was considered. In this case, emplacement would be completed 15.75 years after the ROD and will result in a 7-year decrease in the overall time to complete disposition. Cost estimates have shown a substantial increase in cost over the 10 year disposition case due primarily to the larger throughput capacity of the Front-End Facility.

- ***Post-Operational Period:*** The Post-Operational period overlaps with the Operational Period owing to the fact that hot operations cease at the Front-End Facility before the actual Deep Borehole Disposal Facility disposition activities are complete. Although important, the Post-Operational activities do not impact the date at which disposition will be complete (i.e., the date the last material is emplaced and sealed into a borehole). Decontamination and decommissioning (D&D) activities begin 1 year prior to the end of hot operations and continue for 3 years. Additional time is required to prepare and submit an application to NRC to close the facilities and for NRC review and decisionmaking. In addition, long-term post-closure environmental monitoring of the Deep Borehole Disposal Facility site may be required by the NRC and/or the EPA.

ES.3.6.2 Schedule Uncertainty

The schedule presented in this section has not been optimized. There is considerable potential for reducing both the cost and time associated with the budget and schedule presented here.

The major uncertainty associated with the schedule shown in Figure ES.3.6-1 involves the licensing approach for the Deep Borehole Disposal Facility. In particular, it is assumed that a single license will be granted to operate the facility in contrast to the two separate licences required to construct and operate a mined geologic repository under 10 CFR 60. The two-step licensing procedure, while appropriate for a mined geologic repository, offers no benefit or additional protection to the public in the case of a Deep Borehole Disposal Facility. For a mined geologic repository, considerable mining and construction activity is needed to construct the initial drifts, shafts, etc. of the repository after site characterization is completed. In contrast, in the underground portion of a Deep Borehole Disposal Facility, the final stage of site characterization would be the drilling to target depth of a large diameter borehole that would be used as the first emplacement borehole. Thus, by the end of the characterization period, the construction of the subsurface portion of the Deep Borehole Disposal Facility would be 'substantially complete' as defined by 10 CFR 60.41 and no meaningful purpose would be served by a two-step licensing process for borehole operation. If a two-step licensing process is required by the NRC for the case of the Deep Borehole Disposal Facility, the Pre-Operational Period could be lengthened, and the commencement of hot operations delayed, by as much as six years. The single step licensing process for the Deep Borehole Disposition Alternative is a viable planning basis.

ES.3.7 Criterion 7: Fosters Progress and Cooperation with Russia and Other Countries

While it is not expected that Russia will utilize borehole disposition for their surplus fissile materials, a rapid completion schedule for U.S. borehole disposition may provide an incentive for rapid Russian completion of a different, but comparably effective, 'utilization' disposition option. The Direct and Immobilized Deep Borehole Disposition Alternatives are comparable in this regard. Deep borehole disposition is being considered in the recently completed Joint US-Russian Study of Geologic Disposition Alternatives.

ES.3.8 Criterion 8: Public and Institutional Acceptance

ES.3.8.1 Ability to Create a Sustainable Consensus

The principal public and institutional acceptance issues for the deep borehole disposition alternatives (and the other deep borehole alternatives) are regulatory and licensing related. As with any of the disposition alternatives, local or regional opposition to the project will likely manifest itself in the regulatory and licensing process as well as in other channels. The relative newness of the deep borehole concept may be a source of public and institutional concern and resistance. This will partially, if not entirely, be offset by the technical soundness and low risks of deep borehole disposition.

Deep borehole disposition complies with the national policy of geologic disposal of radioactive wastes and is consistent with international agreements on waste management. The borehole alternatives are the only disposition alternatives (with the exception of the CANDU reactor alternative) that are independent of the civilian radioactive waste management program and provides an important option for fissile material disposition in the event a mined geologic repository becomes unavailable for timely use. Also, cooperative work in this area with Russia could bolster the ‘robustness’ of the path forward for the final disposition of surplus fissile materials.

ES.3.8.2 Socioeconomic Impacts

The Deep Borehole Disposal Facility is likely to be sited in a relatively sparsely populated rural area. During the period of construction and operation, spanning a period of about 14 years, the Facility is likely to become a major employer in the region. Thus, its closure would have a substantial economic impact on the area that would require mitigation. The long term ES&H impacts on the region and the extent of land that would be permanently alienated from use would be minimal.

ES.4.0 ADDITIONAL BENEFITS

ES.4.1 Technology Spin-Offs & Contributions to National and International Initiatives

- The deep borehole disposition concept, when successfully demonstrated through the Fissile Materials Disposition Program, may prove to be a viable low-cost alternative to a mined geologic repository for the permanent disposal of High-Level Waste. In this context, it could be attractive for adoption not only in the U.S. but also in foreign countries that have civilian nuclear power generation programs of modest proportions.

- Successful disposition of excess plutonium in deep boreholes could lead the way for future disposal of other small volume, high isolation priority wastes in deep boreholes. This could include other high risk radionuclides (e.g., minor actinides), or highly toxic materials.

- It is likely that deep borehole disposition could utilize personnel, equipment and methods from the former underground weapons testing program. This would provide ongoing beneficial use of these existing resources, and maintain in a productive way, those capabilities (staff, equipment, competence in drilling, characterization, emplacement and stemming) which might be needed for future testing.

- This work would contribute to the long-standing deep continental drilling program that the NSF has been pursuing. It would also provide a tremendous opportunity to develop a better understanding of deep aquifer water resources.

ES.4.2 Potential for Hybrid Disposition Alternatives

Hybrid options have not been explicitly assessed at this point in the program, so possible pros and cons are speculative. However, the following opportunities for hybrid alternatives exist and should be studied further:

- ***Feed Splitting Based on Feed Quality:*** Borehole disposition appears to be particularly well suited to hybrid options in combination with MOX fueled reactors. Not all of the excess plutonium is readily or economically convertible to reactor fuel. A hybrid option would have the ‘good’ material converted to oxide reactor fuel and material with unsuitable isotopic or chemical composition, morphology, etc. being disposed of in deep boreholes. This could eliminate costly processing of small quantities of Pu with special processing requirements. Either borehole alternative could work in such a hybrid.

- ***Dual Use of Fuel Pellet Fabrication Capabilities:*** The immobilized borehole alternative could use the MOX fuel facility to produce sintered ceramic pellets for borehole disposition and save immobilization facility costs, but would still require conversion of the non-fuel-useable Pu to oxide first. The borehole facility itself could gain from the reduced capacity requirement by reducing borehole numbers, depth or diameter, and by reducing the linear Pu loading factor which would reduce uncertainties in isolation and criticality safety. The reactor facility would benefit from only dealing with material that can be economically converted to fuel.

1.0 DESCRIPTION OF DIRECT DEEP BOREHOLE DISPOSITION ALTERNATIVE: *Direct Disposal of Plutonium Metal/Plutonium Dioxide in Compound Canisters*

The Concept of Fissile Material Disposal in Deep Boreholes

In the direct deep borehole alternative for geologic disposal of surplus fissile materials, the plutonium metal and plutonium dioxide encapsulated in sealed canisters will be emplaced in the lower part of one or more deep boreholes drilled in tectonically, hydrologically, thermally and geochemically stable rock formations (see Figure 1.0-1). The depths considered for the 'emplacement zone' (2-4 km) in the deep boreholes are several thousands of meters greater than those of mined geologic repositories. Once the emplacement zone of the borehole is filled with the emplaced canisters and borehole sealants, the 'isolation zone' extending from the top of the emplacement zone to the ground surface is filled and sealed with appropriate materials.

The direct disposal of plutonium in deep boreholes requires some of the original feed material forms to be first converted to plutonium dioxide while the remaining feed types are repacked in containers without conversion. Desired characteristics of the output disposal form include solidity, high resistance to dissolution by subsurface brines, and thermal and compositional stability. The conversion and packaging process is performed in a Disassembly & Conversion Facility which receives the feed material as plutonium pits, clean plutonum metal, clean oxide, various salts, metal scrap, sand, slag and crucibles, etc. The Facility produces, without further concentration or purification, plutonium dioxide admixtures or plutonium metal as output product. This product is packed in 2R cans, sealed in transportation containers and is delivered by SSTs to the deep borehole disposal facility. At the deep borehole disposal facility, the transportation containers are directly encapsulated in large emplacement canisters without reopening. The emplacement canisters are then lowered into the borehole and sealed in place.

This end-to-end alternative involves safeguards and security systems at various geographical locations. The systems at the existing Disassembly & Conversion facilities will be required to continue to meet DOE/NRC protection requirements. Additionally, the inclusion of the Disassembly & Conversion facilities into the Material Disposition program may require system modifications to comply with IAEA requirements. Process steps conducted at the Borehole and Emplacement Facilities are conducted in part to facilitate the increased proliferation resistance of the material.

This deep borehole disposition alternative meets the requirements of the Fissile Materials Disposition Program in the following ways:

- ***Proliferation Resistance:*** The fissile material will enter the disposition program as an extremely attractive proliferant target. Although the material will be packaged and encapsulated in large canisters prior to being deposited in the borehole the material form itself will not substantially change from a proliferation perspective. For post-closure proliferation resistance, the design concept relies on the great depth and resulting physical inaccessibility of the disposal form emplaced in the deep borehole for security against post-closure recovery of the plutonium from the borehole. Neither the disposal form nor the encapsulating materials will be spiked with fission product HLW to increase its diversion resistance. This is because of potential adverse impacts of the HLW on 1) ES&H and cost of processing and emplacing operations, 2) the release rate of plutonium from the disposal form, and 3) the transport barrier due to the expected stagnant fluid flow in the geosphere. The deep borehole design offers a very high degree of security against post-closure recovery by all except the host government in possession of the disposal site. Recovery by even the host government would be a difficult, expensive, hazardous undertaking that can be easily detected. Thus, it is essentially a method for permanent disposal of the disposed material without the intent of later retrieval. For these reasons, proliferation resistance of this deep borehole disposition alternative is expected to exceed the spent fuel standard after the borehole is sealed, and post-closure surveillance is initiated. Because of the attractiveness of the concentrated plutonium metal and plutonium oxide forms contained within the canisters in this alternative, the proliferation resistance of this alternative is not as high as that in ceramic pellet immobilized disposition.

- ***Isolation of Radionuclides from the Biosphere****:* The deep borehole disposition concept relies on the great distance from the biosphere, and the properties and integrity of the surrounding rock to isolate the emplaced fissile radionuclides from the biosphere over an indefinitely long performance period. Thus, the selection of a site that possesses characteristics which favor long-term isolation will be critical to the success of deep borehole disposition. The expectation that the deep borehole concept will be able to offer such performance is based on 1) the very slow movement of groundwater at great depths, 2) the slow release of radionuclides by the disposal form to the flowing groundwater, 3) the retardation of the movement of dissolved radionuclides in the geosphere by physico-chemical interactions with the rock, 4) the capability to perform the drilling, emplacing and borehole sealing operations without compromising the natural barriers to radionuclide transport provided by the geosphere, or establishing new pathways for transport of the radionuclides to the biosphere, 5) reliance on a spatial separation of the plutonium containers in the boreholes to assure criticality safety, and 6) the use of geologically and geochemically compatible materials to stem and seal the borehole after emplacement. The rate of release of plutonium from plutonium metal and plutonium oxide forms in this alternative is low, but not as low as that of the ceramic pellet immobilized disposition alternative. The environmental impact of the operations phase of this direct deep borehole disposal alternative, however, is less than that of the immobilized deep borehole disposal alternative in that it require less processing and handling prior to emplacement.

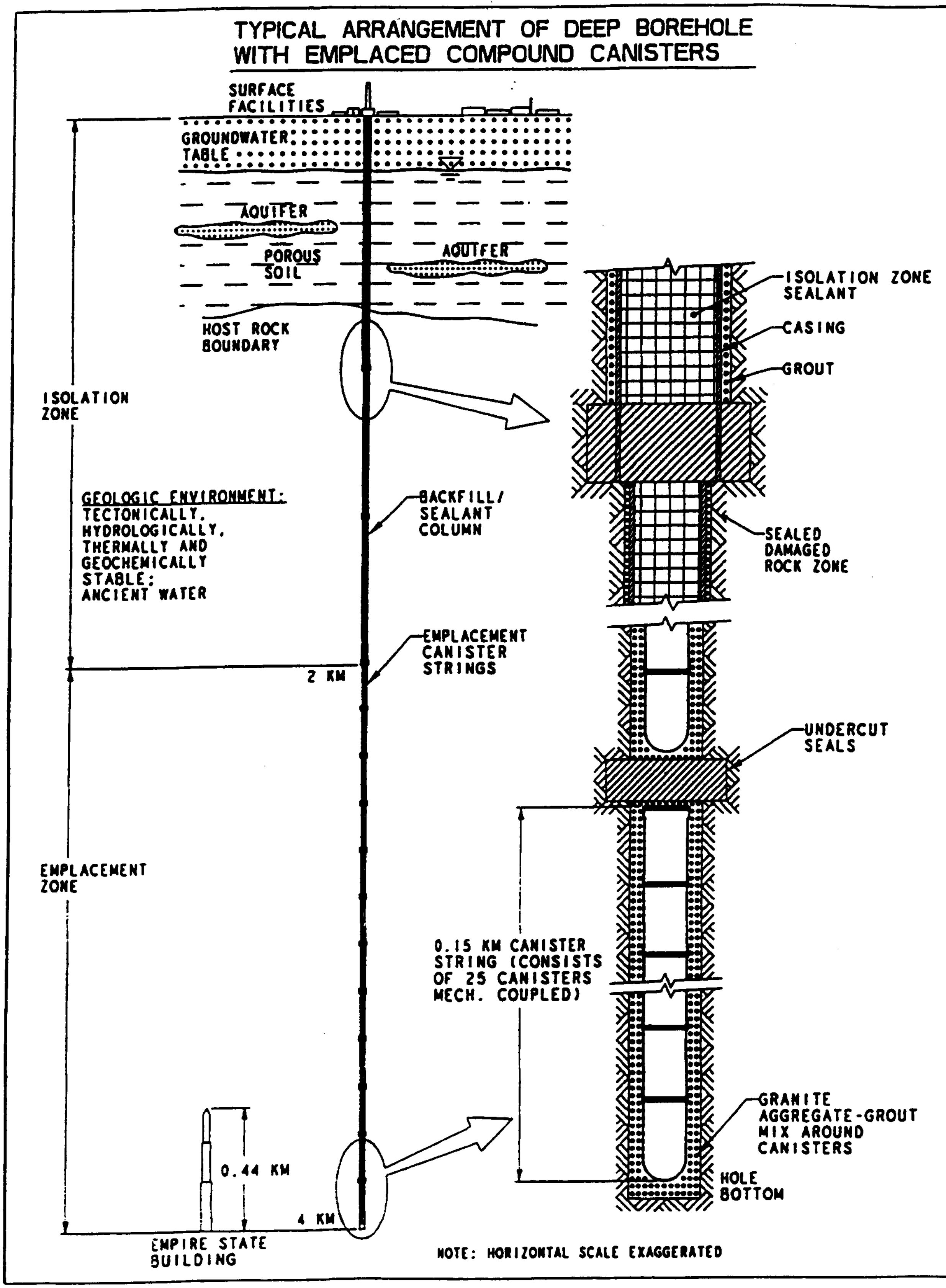


Figure 1.0-1: The Deep Borehole Disposition Concept for Direct Disposal of Plutonium Metal/Plutonium Dioxide in Compound Canisters

- ***Criticality Safety:*** Criticality safety of the direct deep borehole disposition alternative presented in this report relies on 1) the large spatial separation of the plutonium containers in the borehole in the emplaced configuration and in any credible physically disrupted configurations, 2) the absence of any credible slow- or fast-acting mechanisms that could release the fissile materials from the disposal form at a sufficiently high rate, transport the material elsewhere, and reconcentrate it sufficently to achieve a critical mass. Other chemical elements, such as gadolinium and hafnium, that may be added to the canister sealants, and chlorine that may be present in the briny groundwater, absorb neutrons. However, no credit is taken for the presence of these elements either because they may dissolve and separate from the plutonium during transport or because their abundance in the groundwater is uncertain. The occurrence of a criticality event due to such long-term geochemically-mediated reconcentration mechanisms is very unlikely. Nevertheless, the likelihood of such an event will be studied and quantified as a part of the R&D program. Because of the high concentration of the plutonium metal and plutonium oxide forms contained within the canisters in this alternative, criticality safety of this alternative is high as long as spatial separation of the containers can be maintained, but overall is not as high as in the ceramic pellet immobilized disposition alternative.

Assumptions and Design Basis

The top-level assumptions used to develop this end-to-end Disposition Alternative are:

1. **Feed Materials**: The end-to-end Direct Deep Borehole Disposition Alternative will receive the following disposition forms declared excess by weapons programs:

- Pits,	- Clean oxide,
- Clean plutonium metal,	- Impure oxide,
- Impure plutonium metal,	- Uranium/Plutonium oxide,
- Plutonium alloys,	- Oxide-like materials*,
- Alloy reactor fuels (unirradiated),	- Sand, slag and crucibles (SS&C)*,
- Oxide reactor fuels (unirradiated),	- Halide salts*.

* These material categories are expected to be converted to impure oxides as part of the DNFSB recommended 94-1 stabilization program.

2. **Feed Material Throughput**: The total fissile material disposition capacity of the Alternative is 50 t to be disposed of at the rate of 5 t/year over a 10 year disposition period. The surge rate will be 10 t/year.

3. **Facility Siting:** The Direct Deep Borehole Disposition Alternative has a Disassembly & Conversion Facility and a Deep Borehole Disposal Facility located at separate sites. The use of existing facilities and processing capabilities at the Idaho National Engineering Laboratory (INEL), Hanford, and the Savannah River Site (SRS) for front-end processing options were evaluated. All three sites are suitable for plutonium processing and could potentially accommodate front-end processing within existing buildings, though considerable facility modification, decontamination and equipment procurement would be required, depending on the building selected. For the cost analyses given here, it is assumed that the combined Disassembly, Conversion & Immobilization Facility is located at DOE's Savannah River Site (SRS). In contrast, both the design concept and the facility site of the Deep Borehole Facility are generic. The generic site is defined through a set of desirable generic site characteristics that are summarized in this report and identified in greater detail in *Wijesinghe et al.*

(January 15, 1996c). The current working assumption is that the host-rock will be a plutonic/metamorphic crystalline rock in a tectonically, hydrologically, thermally and geochemically stable region. It is assumed that at this generic site, a 4 km deep borehole would be sufficient to ensure long-term performance of the Deep Borehole Disposal Facility. This working assumption will be evaluated for validity in future investigations.

4. **Performance Period:** The fissile materials emplaced at the Deep Borehole Disposal Facility will be required to remain safe for an indefinitely long period because plutonium has a very long half-life (24,400 years) and the half-life of its fissile decay product, uranium-235, is larger by many orders of magnitude (7.1×10^8 years).

On the basis of preliminary assessments of cost-effectiveness and long-term performance of the emplaced disposal form in the deep borehole environment, stable plutonium metal and plutonium oxide forms were selected by the Deep Borehole Disposition Alternative Team for the Direct Deep Borehole Disposal design. In these studies, direct disposal of other feed forms, without conversion to plutonium oxide form, were also considered and rejected for long term performance reasons.

Because of the adoption of a moderate performance disposal form, potential impacts on long term sealing of the borehole due to the presence of degradable materials (such as canister metals) and difficult-to-seal interfaces within the borehole, this Direct Deep Borehole Disposition Alternative will provide a moderate, yet acceptable, level of overall performance. Compared to the Immobilized Deep Borehole Disposition Alternative design, this alternative provides an acceptable, but lower, level of confidence with regard to post-closure isolation, criticality control, and post-closure proliferation resistance, for about 27.7% less cost.

1.1 TOP-LEVEL PROCESS DESCRIPTION

The Direct Deep Borehole Disposition Alternative has key external process interfaces to Feed Source Sites, and internal process interfaces between the Disassembly & Conversion Facility, the Deep Borehole Disposal Facility, the Transportation Task, and the Safeguards & Security Task as shown in Figure 1.1-1.

Surplus plutonium from various source facilities is transported to the Disassembly & Conversion Facility where the different feed forms pass through one or more of the disassembly, conversion, size reduction and packaging processes. The product is packed and sealed in transportation containers which are then shipped to the Deep Borehole Disposal Facility. As shown in the Top-Level Process Flow Diagram in Figure 1.1-2, depending on their chemical compositions and physical attributes, the different feed forms are processed differently in the Disassembly & Conversion Facility. Pits are disassembled and pass through a demilitarization process that produces both plutonium metal and plutonium oxide. Uranium metal recovered in this process is recycled to Y-12. Plutonium metal, metallic alloys, oxide and oxide-like materials are directly repackaged. Metal and oxide reactor fuels are size reduced and packaged. Plutonium in halides and in sand, slag and crucibles (SS&C) is converted by a halide wash-pyrolysis-calcination process to plutonium oxide and packaged. The feed materials selected for conversion are typically those that are too reactive or unstable for direct emplacement in the borehole. All product cans are then packed and encapsulated with sealants in transportation containers. At the Deep Borehole Disposal Facility, these transportation containers are placed and sealed within 6.1 m (20 ft) long emplacement canisters. The emplacement canisters are assembled into 152 m (500 ft) long canister strings, which are lowered into the borehole and sealed in place.

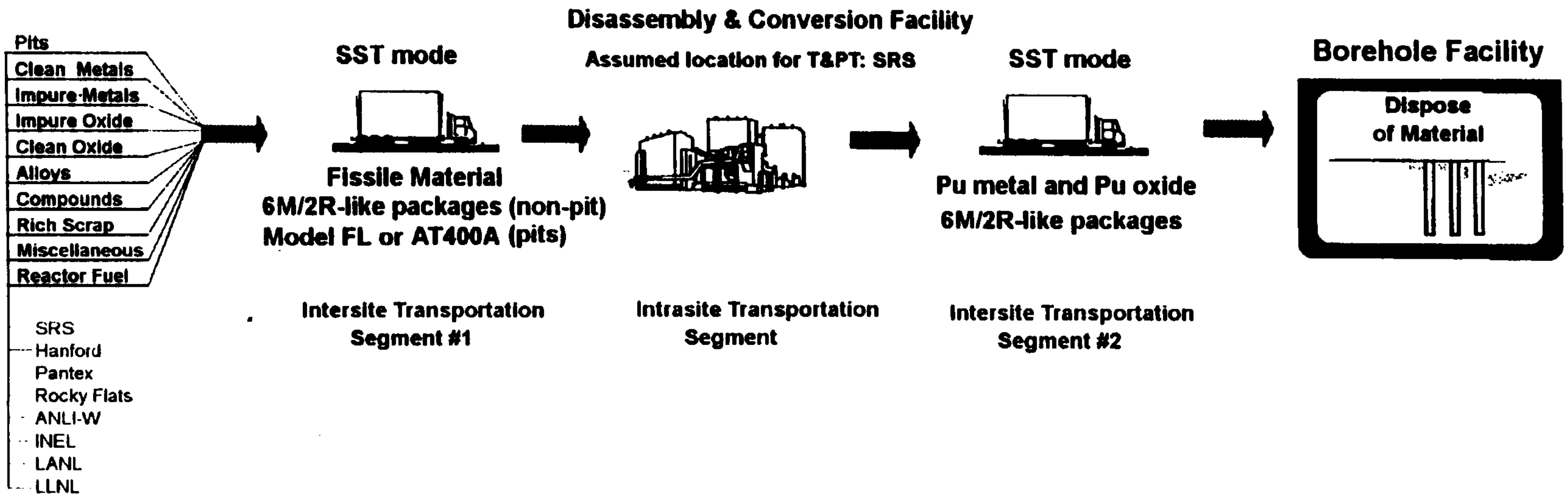


Figure 1.1-1: External Interfaces of the Direct Deep Borehole Disposition Alternative

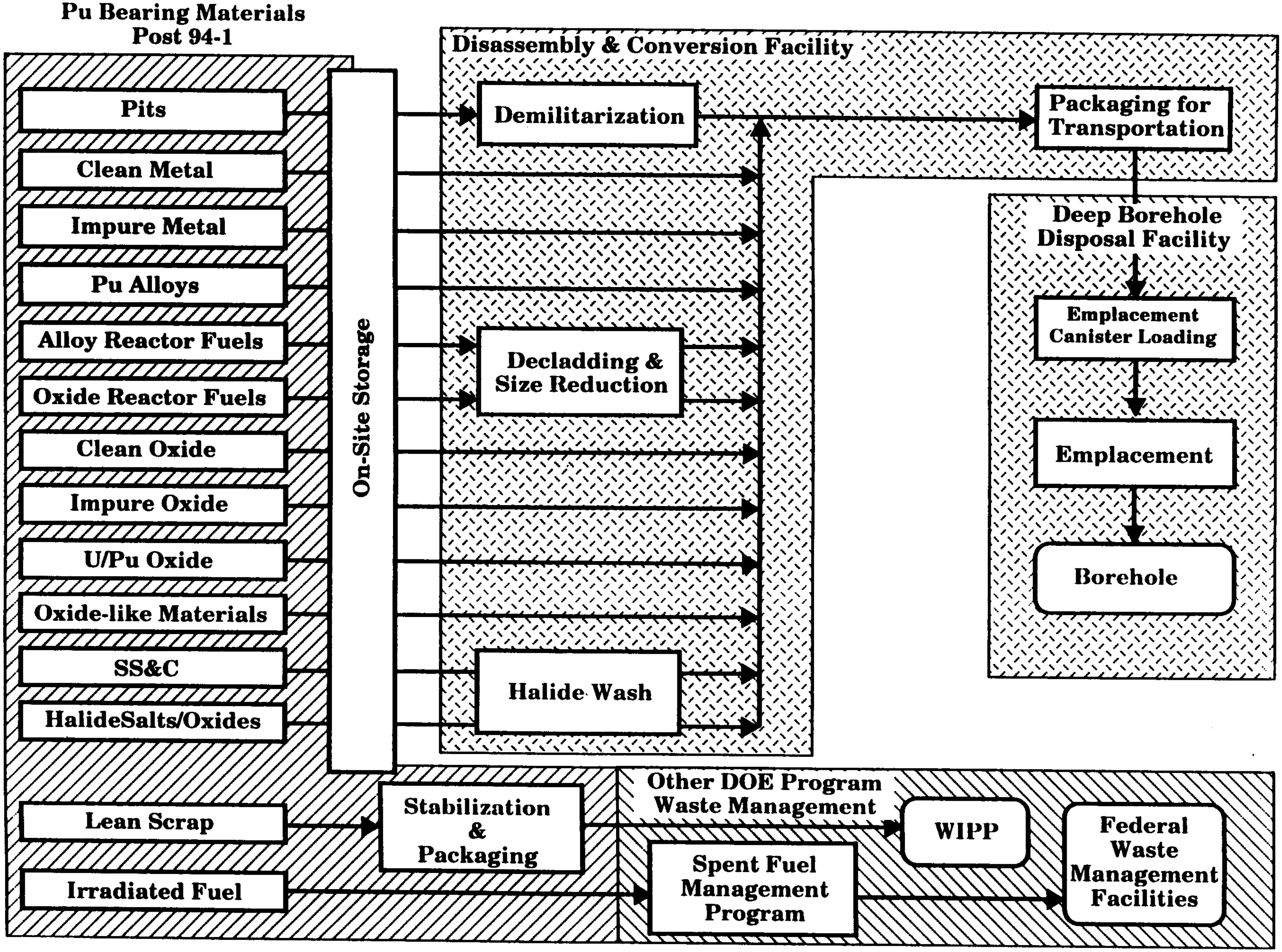


Figure 1.1-2: Top-Level Flow Diagram for the Direct Deep Borehole Disposition Alternative

1.2 MASS BALANCE FLOW SHEETS

The Pu mass balance flow sheet for the 10 year disposition campaign for the Disassembly & Conversion Facility and the Deep Borehole Disposal Facility is given in Figure 1.2-1. This flow sheet shows the fissile material contents in the incoming feed materials, the outgoing products, the airborne emissions to the atmosphere, the solid waste streams and the liquid waste streams (if any) of each facility. Although the total Pu content in the solid waste stream is several times the significant Pu quantity (SQ), the solid waste stream is very dilute in Pu concentration and consists of transuranic (TRU) and low-level (LLW) wastes. The TRU waste is shipped to the Waste Isolation Pilot Plant (WIPP) while the LLW is shipped to a shallow land burial site for disposal.

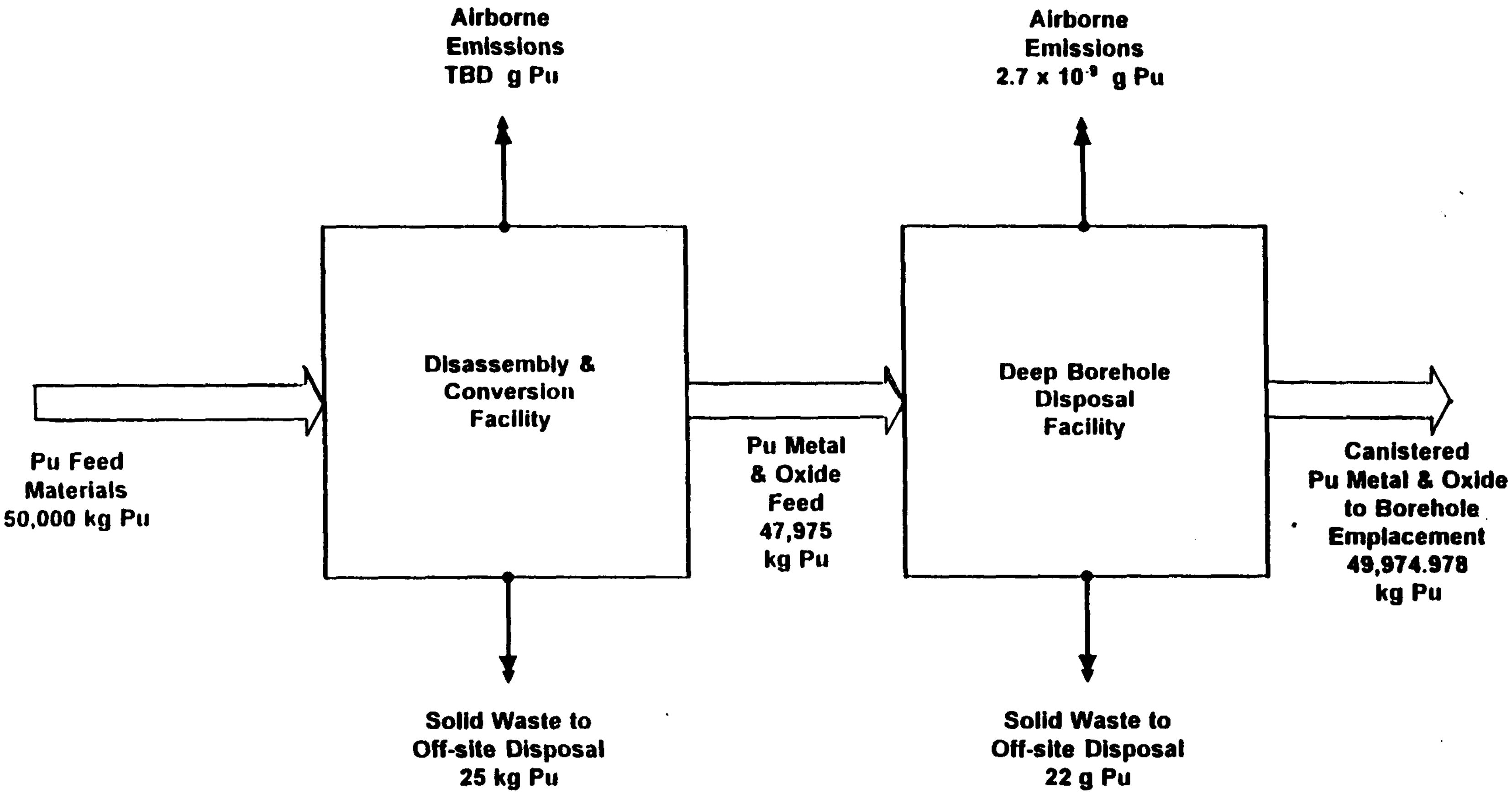


Figure 1.2-1: Plutonium Mass Balance Flow Diagram for the Direct Deep Borehole Disposition Alternative

1.3 DISASSEMBLY & CONVERSION FACILITY

1.3.1 Facility Description

Functional Description

The Disassembly & Conversion Facility will produce product cans filled with plutonium bearing metal and oxides. The feed materials are plutonium pits, clean metals, impure metals, impure oxide, Pu alloys, alloy reactor fuels, oxide reactor fuels, clean oxide, impure oxide, U/Pu oxide, oxide-like materials, sand, slag & crucibles, and halide salts. The facility will declassify and convert pits to plutonium metal ingots, and size-reduce large metal and oxide reactor fuels. Clean and impure oxides are not processed further. Oxide-like materials, sand, slag & crucibles, and halide salts are expected to be converted to impure oxides as part of the DNFSB recommended 94-1 stabilization program in which case impure oxides would be processed instead by the facility. All converted materials and unconverted metals and alloys are repackaged in welded cans with void filler. The void filling is required to satisfy disposal form acceptance criteria for deep borehole disposition. This facility will be a non-reactor nuclear facility that will handle Category I quantities of plutonium. The product from this facility will be repackaged material that can be shipped directly to the deep borehole facility for emplacement.

The facility process flow diagram for the Disassembly & Conversion Facility is given in Figure 1.3.1-1. A description of each of the processes shown in this diagram is given below.

1. *Truck and CRT Unloading (DC-01):* Material shipments will be delivered to a Truck and Container Restraint Transport (CRT) Unloading dock where the delivery vehicles (SSTs/SGTs) will be washed and smear checked, and the packaged plutonium cargo unloaded. Initial assessments of radiation levels and container breaches are made during the unloading process to ensure a safe configuration for temporary storage while awaiting receiving and inspection. Shipping papers are checked, TIDs inspected, and neutron counts are made on the packages. Emptied shipping containers are inspected, decontaminated (if necessary), and prepared for return with the delivery vehicle.

2. *Receiving (DC-02):* Receiving includes material confirmation, accountability, safety, and inventory measurements. If the storage criteria are not met by the shipping containers, the plutonium cargo is unpacked from the shipping containers, and re-packaged in suitable storage container in concert with the measurement activities. The repackaged material is placed in the storage vault where it will await processing. Contaminated containers are handled in a decontamination station where the material is retrieved and repackaged, and the containers are decontaminated.

3. *Gas Sampling (DC-03):* All pits are gas sampled to check for potential contamination. Contaminated pits are sent to *Special Recovery (DC-04),* while uncontaminated pits are sent to *Pit Disassembly (DC-05).*

4. *Special Recovery (DC-04):* Contaminated pits are disassembled and the resultant parts are cleaned. Plutonium-bearing parts are separated out from the balance of the material. This operation consists of the following glove box operations: disassembly, tool storage, bakeout, NDA, and sub-component packaging.

5. *Pit Disassembly (DC-05):* Pits are bisected to allow for plutonium removal using hydriding. This operation consists of one work station for receiving and one work station for the pit bisector.

6. *Hydride/Dehydride (DC-06):* Plutonium is reclaimed from the bisected parts and cast into metal ingots. The hydride/dehydride process is the method used to reclaim the plutonium and produce metal. This operation consists of several accountability work stations and a work station for the hydride unit.

7. *Passivation Furnace (DC-07):* A passivation furnace will convert glove box sweepings into stable oxide. This operation will consist of an open work station and a work station containing the passivation furnace.

8. *Oralloy Decontamination (DC-08):* Oralloy (Oy) having economic value will be decontaminated with an acid bath, rinsed, and packaged for shipment to a reprocessing facility.

9. *Concentration (DC-09):* Plutonium carried into the leachate from the *Oy Decontamination (DC-08)* will be concentrated, and the reclaimed acid will be returned to the Oy Decontamination process.

10. *Denitration (DC-10):* The plutonium-bearing concentrate from *Concentration (DC-09)* will be denitrated to remove NO_x from the concentrate producing a mixture of plutonium and uranium oxides.

11. *Size Reduction (DC-12):* Fuel elements that are too large will be chopped using hydraulic shears The glove box for this operation has a loading workstation, an unloading workstation, and a workstation that contains the chopper.

12. *Pyrolysis & Calcination (DC-13):* Carbonaceous-containing materials will go through pyrolysis and calcination to reduce the plutonium to a stable oxide, providing a uniform size and composition. Calcination heats feeds up to 1000°C in an air atmosphere to remove water and other volatiles and convert materials to oxides.

13. *Off-Gas Treatment (DC-14):* The off gas treatment will be located close to the pyrolysis and calcination process. The equipment will clean the gas before releasing it to the common ventilation system. Off-gases will be quenched, filtered, scrubbed, and vented through HEPA filtration. The off gas treatment system will remove gases such as water, NO_x, SO_x, and particulates. The particulates will be returned to the calcination process.

14. *Halide Wash (DC-15):* Halide-containing material will be washed with water to dissolve the halide. A small amount of acid may be added to enhance the dissolution of the halide. The glove box for this operation must be resistant to halide solutions and consists of a receiving work station, and a dissolution work station. The solids from this step will be sent to *Calcination (DC-13)*. The solution will be sent to *Precipitation & Filtration (DC-16)* to remove dissolved plutonium.

15. *Precipitation & Filtration (DC-16):* The solution from the *Halide Wash (DC-15)* will be filtered and the solids sent to calcination. The filtered solution will be precipitated to remove dissolved plutonium. The precipitation operation will add oxalic acid to the solution and precipitate the plutonium out of solution. The solution will be filtered again, and the plutonium oxalate will be sent to calcination. The chloride solution will

be sent to aqueous waste processing. The glove box for this operation must be resistant to halide solutions and consists of solution storage tanks, precipitation, and a filtration work station.

16. *Interim D&C Storage (DC-17):* The Interim D&C Storage is a vault that stores the repackaged material until it is shipped to the deep borehole disposal facility.

17. *Repackage with Void Filler (DC-18):* Materials will be packaged in a compound canister. Those materials that will leave voids in the canister due to the size and shape of the material, will have a filler packed with the material to eliminate the potential for voids.

Plot Plan

The Disassembly & Conversion Facility plot plan is shown in perspective view in Figure 1.3.1-2. Note that the size, number and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only. The major structures on the site are as follows:

- Plutonium Processing Building.
- Radwaste Management and Radiologically Controlled Maintenance Buildings.
- Product Storage Building.
- Miscellaneous support buildings, including the Administration Building, the Support Utilities Building, the Industrial Waste and Sanitary Waste Treatment Buildings, the Shops Building, and the Warehouse.
- Disassembly & Conversion Facility forced draft cooling tower.
- Disassembly & Conversion Facility ventilation exhaust and boiler stacks.

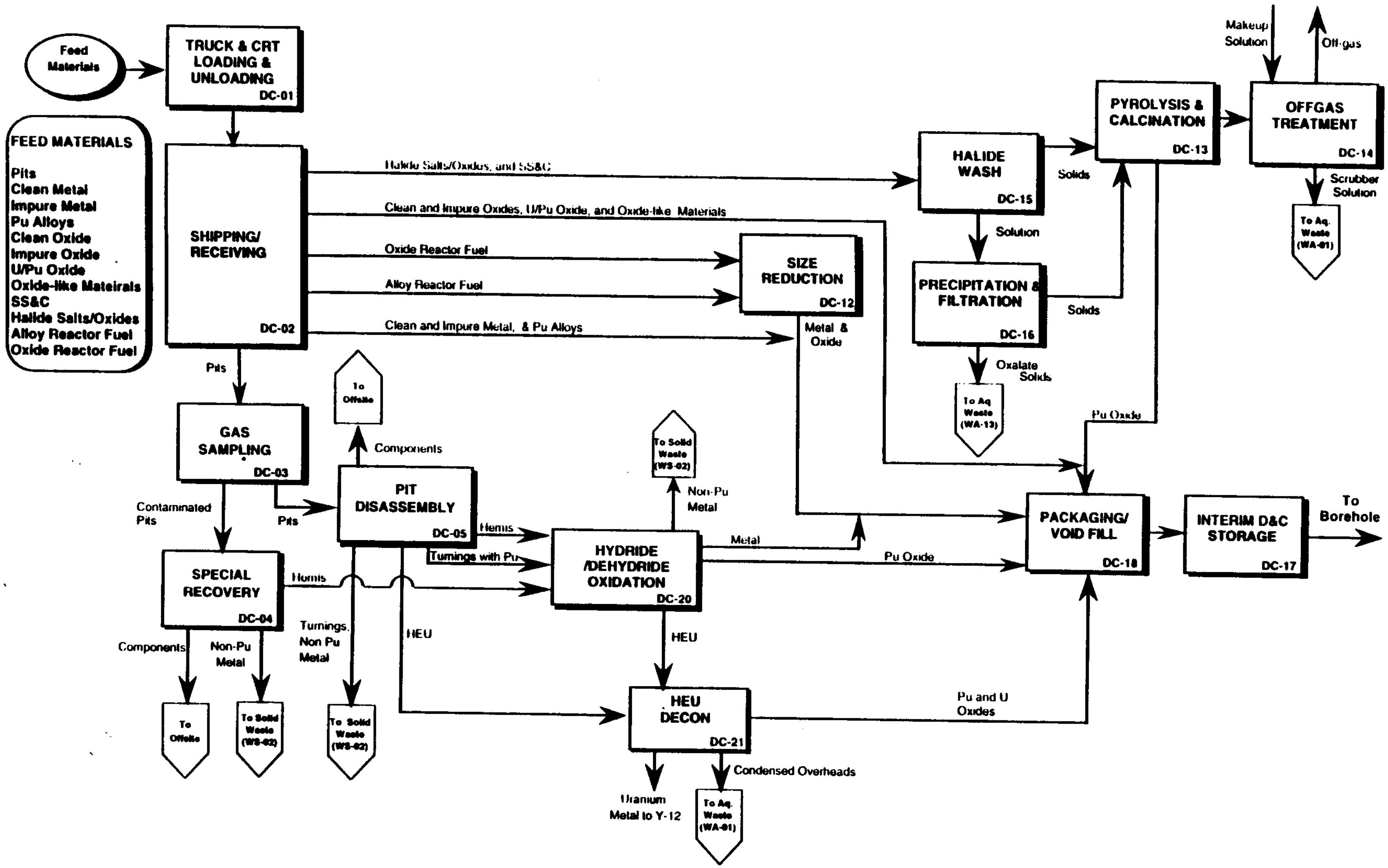


Figure 1.3.1-1: Process Flow Diagram for the Disassembly & Conversion Facility

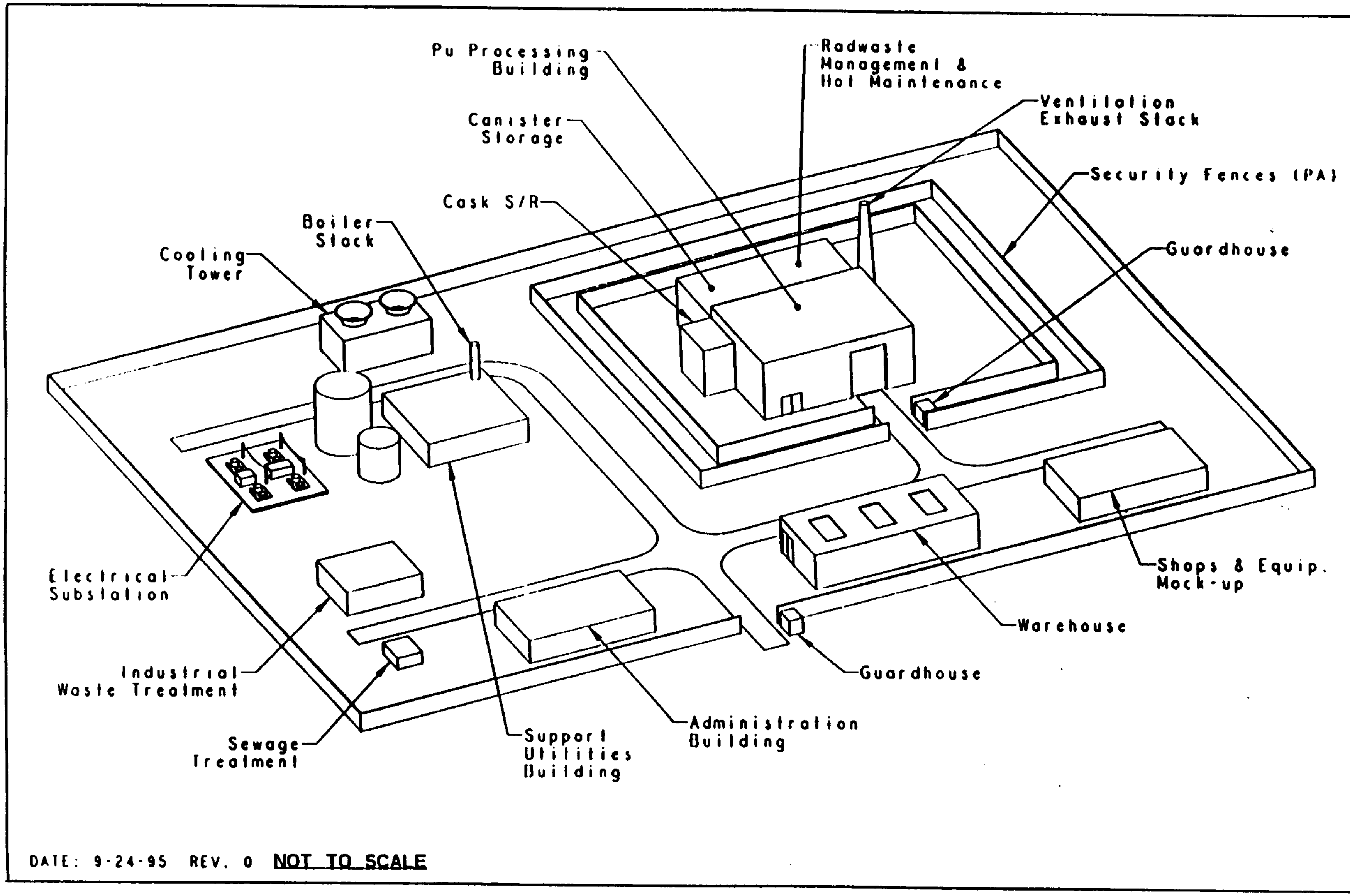


Figure 1.3.1-2: Perspective View of the Disassembly & Conversion Facility

- Perimeter Intrusion Detection, and Assessment Systems (PIDAS) double fence surrounding the site protected area.
- The Limited area and Protected Area guardhouses
- The site Electrical Substation.

Building Descriptions

The Disassembly & Conversion Facility data are summarized in Table 1.3.1-1.

Table 1.3.1-1: Disassembly & Conversion Facility Data

Building Name	Footprint (m^2)	Number of Levels	Special Materials	Construction Type
Pu Processing Building	4,455	2	SNM	Reinforced Concrete
Radwaste Management Building	1,162	1	SNM	Reinforced Concrete
Radiologically Controlled Maintenance Building	1,394	1	SNM	Reinforced Concrete
Product Storage Building	698	1	SNM	Reinforced Concrete
Support Utilities Building	1,394	1	None	Metal Frame
Administration Building	1,672	1	None	Metal Frame
Warehouse	465	1	None	Metal Frame
Shops Building	2,230	1	None	Metal Frame
Generator Building	186	1	None	Metal Frame
Industrial Waste Treatment Building	929	1	None	Metal Frame
Sanitary Waste Treatment Building	149	1	None	Metal Frame
Guardhouses (2)	149	2	None	Reinforced Concrete
Cold Chemicals Storage Building	233	1	None	Metal Frame
Cooling Tower	929	-	-	-

Plutonium Processing Building

The Plutonium Processing Building is a reinforced concrete structure housing a central processing area where the main disassembly and processing is located, surrounded by various support areas. The building houses the following main functional areas:

- Areas for receiving and shipping plutonium as either feed materials or metal/ oxide product in Safe Secure Trailers (SSTs).
- A shipping and receiving area for cold chemical feed materials and other non-radioactive materials.
- Facilities for accountability measurements of the special nuclear material received or shipped.
- A storage vault for special nuclear material received.

- Glove box areas for disassembly and plutonium processing.
- An analytical laboratory for analysis of process samples.
- An equipment decontamination area for decontamination, maintenance and repair of process equipment.
- Facilities for mechanical and electrical support systems and clean equipment maintenance.
- A scrap treatment area to allow treatment and recycle of plutonium from contaminated process materials.
- An area for entry control to the facility, personnel rooms, change rooms and health physics operations.
- A control room.
- HVAC equipment.

The plutonium processing equipment is housed in glove box enclosures located in processing rooms. Glove box equipment layout is grouped by primary process operations. Maintenance of equipment within the process glove boxes will be by gloves after removal of plutonium from the process equipment. The process support systems are primarily housed within the process building with the exception of the process gas supply systems, which will be located in the yard adjacent to the process building. Glove boxes containing plutonium metal will be operated under a nitrogen atmosphere to prevent a plutonium metal fire.

The plutonium feed material storage and handling system consists of a plutonium shipping container crane; a plutonium storage container unloading, weighing, bar code reading and assay device; and a plutonium storage container transfer device. A plutonium storage vault meeting the requirements of DOE Orders 6430.1A Section 1305 with a capacity of six months feed and served by a stacker-retriever is provided.

The process material handling system will consist of remotely operated conveyors within and between glove box enclosures to provide for confined material transfers. A remotely operated stacker-retriever will provide material transfers to and from storage of plutonium-containing materials, samples, etc. within a storage vault adjacent to the process glove box areas.

Equipment, piping and other components can be decontaminated in the equipment decontamination area. A scrap treatment area has been provided to allow treatment of off-specification process materials, contaminated equipment and components to recover plutonium and recycle it back into the process.. Also, decontamination and leaching equipment will be provided to allow recovery of plutonium from process equipment and return the solutions to the process. Other off-specification materials from the process will be recycled to the appropriate equipment in the plutonium process.

An analytical laboratory will be provided to allow analysis of process materials to assure product specifications and plutonium MC&A goals are met. The laboratory will be provided with mass spectrographs, calorimeters, nondestructive assay equipment, radiological chemical analytical equipment, etc. as necessary to provide a fully self-sufficient onsite laboratory to meet the needs of the facility.

Product Storage Building

Storage of product drums is provided in a the Product Storage Building equipped with drum storage racks, a remotely operated forklift (or stacker-retriever) and a computerized tamper-indicating system to monitor and permit only authorized drum movement. Initial onsite storage capacity is one year with space provided for expansion of this capacity to the full 10 years of operation.

Radiologically Controlled Maintenance Buildings

The Radiologically Controlled Maintenance Building is located inside the inner security fence adjacent to the Plutonium Processing Building. It provides facilities for the maintenance and repair of process equipment from the Plutonium Processing Facility or the Radwaste Management Building. Shop areas are provided for equipment receiving and decontamination, equipment disassembly and repair, machining, electrical and controls repair, and equipment testing. An area is also provided for entry control to the facility, personnel change rooms and a health protection room. Equipment is decontaminated prior to transfer to the Radiologically Controlled Maintenance Shop. Failed process equipment and other low level waste materials generated in shop operations will be transferred to the adjacent Radwaste Management Building to be packaged for shipment offsite.

Radwaste Management Facilities

Waste management facilities to handle the radwastes generated by facility operations are located in the Radwaste Management Building immediately adjacent to the Plutonium Processing Building.

Radwaste treatment systems housed in this area include the following:

- *Process liquid radwaste*: The process liquid radwaste treatment facilities include the recycle waste evaporator, nitric acid recovery system, and the LLW/TRU radwaste solidification systems. Since these systems will handle relatively low-activity waste streams, they will generally be located in controlled access processing rooms equipped with room ventilation confinement zoning appropriate to the expected levels of contamination within the room. Mixed waste will be segregated from other waste forms and stored for shipment to offsite treatment facilities.

- *Process solid radwaste*: Process solid radwaste treatment systems will also be housed in the Radwaste Management Building. Solid waste generated from the glove box operations will generally be handled and processed in glove box enclosures. Where fume or dust generation is anticipated, (i.e., cementing, volume reduction, etc.) equipment will be installed in glove box enclosures supplied with local filters, mist eliminators, condensers, etc. as required to minimize the spread of contamination to the glove box ventilation system. The equipment will be further isolated in processing rooms provided with ventilation zoning appropriate to the levels of contamination expected. Solid wastes generated within the process will be segregated into low level, TRU, and mixed waste. Solid waste assay, segregation, decontamination, and volume reduction facilities will be provided to minimize the volume of waste shipped from the facility. Waste packaging and shipping facilities for both LLW and TRU waste will be provided. Solid radwaste consisting of process gaseous radwaste equipment components such as local sintered stainless steel filters, condensers, etc. are generally not expected to be highly contaminated and will normally be designed to be contact handled and processed within glove box enclosures or bagged out into suitable containers.

- *Gaseous Effluents:* Gaseous effluents will be filtered, condensed, scrubbed, absorbed, etc. as required to meet DOE and other applicable regulatory requirements. Local condensers, mist eliminators, and sintered metal filters with blowback to the process are provided for operations where particulate generation is expected. HEPA filters are provided at both inlets and outlets of glove box enclosures handling plutonium. Two stages of HEPA filters are provided in the process off-gas system and a NO_x absorption column and appropriate heaters, knockout drums, etc. as required to assure that releases are below acceptable limits. Chemical removal of NO_x may be required to meet effluent limits. Discharge of building HVAC exhaust air will be through three stages of HEPA filters prior to release.

- *Utility wastewater discharges:* These discharges, including cooling tower and boiler blowdown, cold chemical area liquid effluents and nonradioactive liquid ceramic additive liquid wastes will be treated and discharged in an industrial wastewater treatment plant to assure that wastewater discharges meet applicable environmental standards. An onsite sanitary treatment plant will treat sanitary wastes generated from Disassembly & Conversion Facility operations.

Balance of Plant Facilities

In addition to the process facilities described in the sections above, the Disassembly & Conversion Facility includes the following facilities and systems:

- An Administration Building containing management and staff offices, meeting and conference rooms, visitor control, and cafeteria.
- A Warehouse for general storage and delivery.
- The Support Utilities Building, located outside the inner security fence, including raw water treatment systems, water storage tanks, fire water storage, fire-water pumps, chilled water cooling, steam heating boiler, and plant compressed air systems.
- An metal framed standard construction Shops Building for housing clean maintenance and repair shops.

- The Industrial Waste Treatment Facility for the receipt, treatment and disposal of noncontaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system.
- An onsite sanitary treatment plant to treat sanitary wastes generated by the Disassembly & Conversion plant operations.
- A Sanitary Waste Treatment Facility
- Building heating, ventilating and air conditioning (HVAC). These systems use a central chilled water system for building cooling.
- A cooling tower: a multiple cell, wood construction, induced draft, crossflow type tower with a capacity to provide cooling for both the process and HVAC systems. Cooling of process equipment, provided by a closed-loop cooling water system that is cooled with cooling-tower water in plate-type heat exchangers. The monitored closed cooling loop isolates any radioactive contamination should a leak occur in a piece of process equipment. All cooling water systems are connected to the cooling tower system described above.
- A central steam plant. This is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces steam which is distributed around the site by outside overhead piping.
- Compressed air systems. These include plant air, instrument air and breathing air. Redundant reciprocating air compressors provide the compressed air. The plant air system is provided through a receiver set. Instrument air is dried in dessicant type air dryers and is supplied to a piping distribution system from a separate air receiver. The breathing air system provides air to breathing air manifolds located throughout the Plutonium Processing Building.
- Electric power. The site receives electric power at 13.8 kV from the utility grid system and distributes it onsite at the required voltages. The Electrical Substation has a capacity of 5 MW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 700-kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety-related systems during a power outage. Uninterruptible power supply (UPS) systems ensure continued operation of safety related equipment and systems during a power outage.
- A perimeter security system, including a guardhouse at each entry point to the site or to the inner security area. All facilities where radioactive materials are handled, and facilities necessary for the safe operation of the process facilities are surrounded by double security fences within the outer site perimeter fence.

1.3.2 Generic Site Description

Site Map

The Disassembly & Conversion Facility Site Map is shown in Figure 1.3.2-1. The site is surrounded by multiple fences for security. The main processing facilities are located within a double security fence and include the Plutonium Processing Facility and

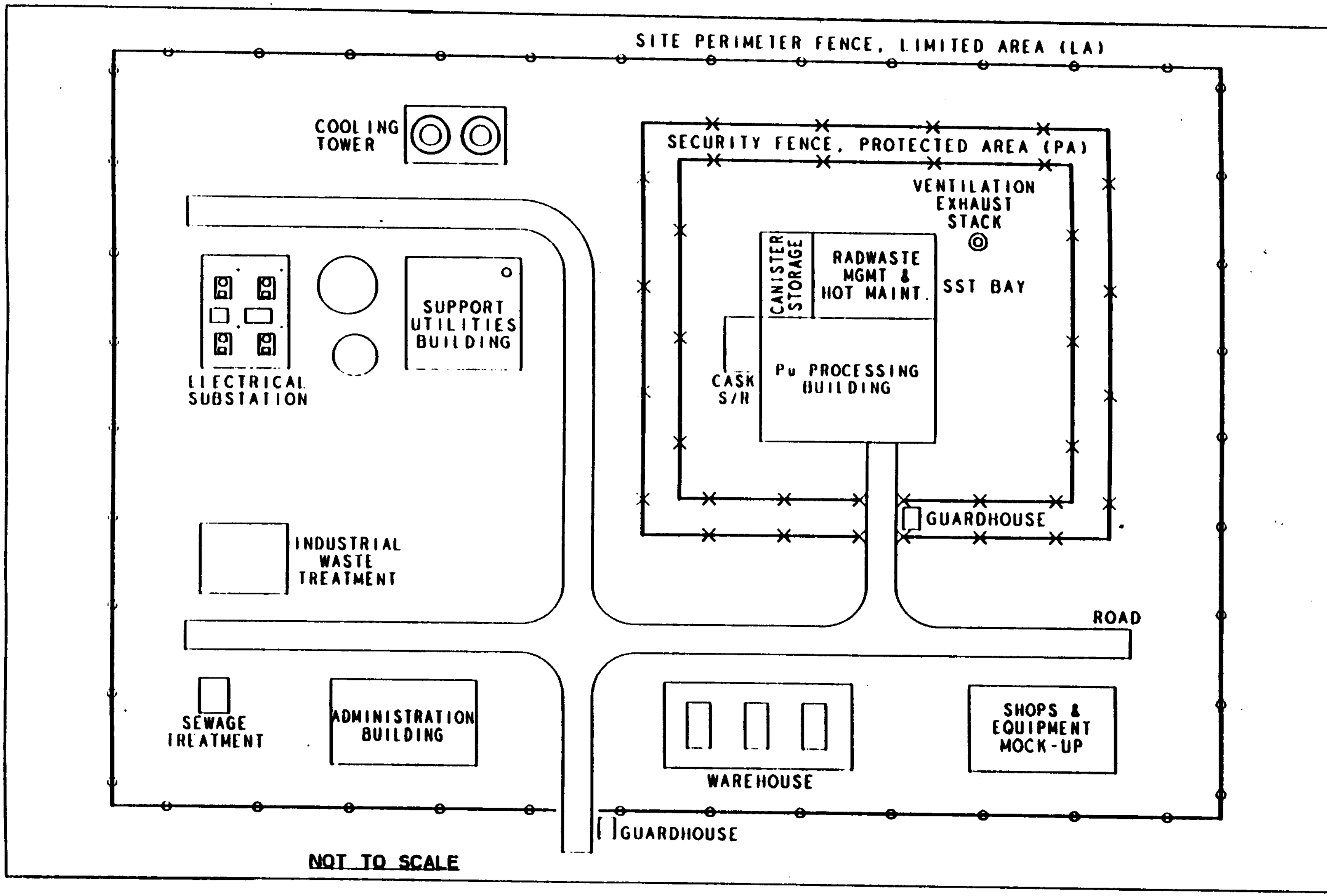


Figure 1.3.2-1: Site Map of the Disassembly & Conversion Facility

the adjacent Plutonium Operations Support Building. Support facilities including the Administration Building, Warehouse, the Support Utilities Building, the Industrial Waste Treatment Building and the Sanitary Waste Treatment Facility are located outside the security area, but within the overall Site Perimeter Fence.

Access to the site is controlled at guardhouses located at both the perimeter fence and at the security fence surrounding the process area. A ventilation exhaust stack discharges process and ventilation air from the Plutonium Processing Building. Other sources of airborne emissions from the site are the boiler stack at the Support Utilities Building and HVAC exhaust outlets from the non-process support buildings outside the security fence. All liquid effluents from the site are from either the Industrial Waste Treatment Facility or from the Sanitary Waste Treatment Facility.

1.3.3 Facility Operation

The Disassembly & Conversion Facility would process 5 t of surplus fissile materials annually over its operational life of 10 years. Operations will use three shifts per day, seven days per week. Allowing normal time for remote maintenance, material control and accountability, etc., normal plant availability is considered to be 200 days per year. Nominal throughput is, therefore, 25 kg of Pu per day.

1.3.4 Waste Management

Waste Management Function

Waste management processes for the Disassembly & Conversion Facility includes waste handling and treatment operations for processing the transuranic (TRU) waste, low-level waste (LLW), hazardous mixed waste (MW), and industrial waste in aqueous, organic liquid, or solid form generated from the conversion operations. The waste management operations will be in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act (RCRA). It is assumed that TRU waste generated from Disassembly & Conversion Facility operations will be disposed of at the Waste Isolation Pilot Plant (WIPP) in accordance with WIPP Waste Acceptance Criteria.

Radioactive wastes are processed in a Radwaste Management Building adjacent to the Process Building. The waste treatment processes include assay examination, sorting, separation, concentration, size reduction, organic destruction, and thermal treatment. The wastes are converted to water meeting effluent standards, grouted cement, or compacted solid waste as final form products for disposal. Solid TRU wastes are packaged, assayed, and certified prior to shipping to the WIPP for permanent emplacement. Low-level solid wastes are surveyed and shipped to a shallow land burial site for disposal. A small quantity of solid mixed waste (mainly leaded glove box gloves) are packaged and shipped to a DOE waste treatment facility pending future processing. The waste treatment processes also includes equipment and waste container decontamination operations.

1.3.5 Intrasite Transportation

Plutonium containing metal or oxide will be received at the Plutonium Processing Building via Safe-Secure-Trailer (SST). Since all operations on SNM are performed within the Plutonium Processing Buildings, there will be no intrasite transport of radiological materials. Any radiological material shipped offsite will be in the form of waste which will be packaged and shipped from Plutonium Processing Building in accordance with DOT requirements.

Hazardous chemicals will be received from offsite and stored in the building where they are used so no intrasite transport is required. Hazardous chemicals will be used in the Plutonium Processing Building, the Support Utilities Building, the Industrial Waste Treatment Facility and the Sanitary Waste Treatment Plant.

1.3.6 Safeguards and Security

The domestic safeguards and security program is designed to ensure that surplus fissile materials, which are converted into long-term disposition forms, meet security objectives. The vulnerabilities, designs, technologies, and operations associated with Safeguards and Security are interrelated in many areas relative to physical protection, nuclear materials control and accountability (NMC&A), and international safeguards containment and surveillance (C/S).

DOE interests are protected against a range of threats which include unauthorized access; theft or diversion of special nuclear material; industrial, radiological, or toxicological sabotage; espionage; loss or theft of classified information or property; and other hostile acts which may cause unacceptable adverse impacts on national security or on the health and safety of DOE and contractor employees, the public, or the environment. The US regulatory requirements are found in DOE Orders, NRC regulatory documents, and US Code of Federal Regulations. The domestic threat is based upon the US DOE Design Basis Threat, and the Fissile Material Dispositions Program's Threat Guidance, and is potentially composed of insiders and outsiders.

Protection of surplus fissile material during all phases of the operation requires stringent protection measures to deter, detect, assess, delay, and respond to adversary attacks.

Protection planning is based on DOE/NRC requirements and site specific vulnerability assessments (VA). The VAs identify the appropriate levels of protection for each potential type of material against each potential type of adversary and threat (e.g. theft or sabotage). Material is protected while in-storage, in-process, in-transit, and final disposition.

1.3.6.1 Physical Security System Requirements and Facilities

Programmatic activities shall be conducted within designated security areas (i.e., Property Protection, Limited, Protected, Material Access). Structures and protection measures utilized as security barriers will incorporate appropriate levels of adversary delay and denial. Barriers accommodate concentric layers of graded protection and defense-in-depth measures. Types of passive barriers include fencing, hardened walls, vault doors, locking systems, geologic formations, etc. Active barriers may be used, and include dispersed foam, smoke, etc. Associated delay levels are determined by barrier technology data and/or the conduct of vulnerability assessment performance testing. Detection and assessment will be accomplished through the most cost-effective integrated use of alarms, personnel and material sensors, closed circuit television, lighting, and protective force personnel, and accommodate concentric layers of graded protection and defense-in-depth measures. These measures include permanent or temporary Perimeter Intrusion Detection and Assessment Systems (PIDAS) with multiple complimentary sensors, interior alarms, explosive and metal detectors, SNM monitors, primary and secondary alarm monitoring and communication consoles, dedicated uninterruptable power sources, protective patrols, etc.

1.3.6.2 Materials Control and Accountability

The material control and accountability (MC&A) program includes a system of checks and balances sufficient to detect and deter the unauthorized diversion or removal of special nuclear material from its authorized location and provide assurance that nuclear materials are in their authorized locations and are being used for authorized purposes. The facility's nuclear MC&A program, consistent with a graded materials safeguards and security program encompasses the systems and measurements necessary to track nuclear material inventories, control access, provide timely detection capability for loss and diversion of nuclear materials, and assure the integrity of the systems and measurement-in-place.

1.3.6.3 IAEA Safeguards Requirements

The International Atomic Energy Agency (IAEA) is responsible for independently verifying that significant quantities of nuclear material have not been diverted for unauthorized uses. The primary goal of the IAEA is to detect the theft or diversion of one 'significant quantity' of SNM within a specified period of time. The time period is intended to be related to the time required to convert different forms of nuclear material to the metallic component required for a nuclear explosive. One significant quantity (SQ) is 8 kg *(IAEA Safeguards Glossary).*

Following pit disassembly and conversion, material storage and processing activities at the Disassembly & Conversion Facility shall be designed/modified to accommodate international and domestic safeguards, security protection, and transparency requirements. The International Inspection Area is used by international inspectors for inspection and verification of Surplus Material. The physical inventory verification (PIV) method is dependent on the type and form of material. The inspection area houses international agency provided equipment to conduct authorized surveillance without allowing access to classified information. These activities may also include site visits for the purpose of reviewing documentation and recorded information from installed instrumentation and CCTV cameras. Special uninterruptable power supply (UPS) and other systems may be required by international agreements. International requirements are found in IAEA Information Circulars, and the *Safeguards Criteria 1991-1995*, Department of Safeguards, IAEA, Vienna, Austria, November 1990.

1.4 DEEP BOREHOLE FACILITY

Facility Design Criteria and Design Basis

In this Section**,** the design criteria and assumptions used to guide the design of the Deep Borehole Disposal Facility for the Direct Alternative are:

1. **Feed Form Type, Size:** The fissile material feed will be in the form of plutonium metal / plutonium dioxide in product cans sealed in 2R PCVs about 14 cm (5.5 in). in diameter and 50.8 cm (20 in.) high.
2. **Plutonium Throughput:** The total fissile material disposal capacity of the Facility is 50 t of plutonium. The disposition rate is 5 t/year over a 10 year operational period. The surge rate will be 10 t/year.
3. **Feed Form Plutonium-Loading Level and Throughput**: The plutonium loading per PCV is 4.5 kg and about 1,111 canisters will be disposed of annually.
4. **No Radioactive Deterrent:** The disposal form considered for deep borehole disposition will not be spiked with high level nuclear waste.
5. **Criticality Safety:** The criticality safety of the plutonium-loaded product cans and the PVCs during intrasite transportation, processing, emplacement, and post-emplacement performance in the short-term, will be ensured by spatial separation. However, for additional long-term insurance, a package of neutron poisons (i.e., absorbers) will be added to the disposal form during conversion at the Disassembly & Conversion Facility. Criticality safety during the long-term post-closure performance period when the plutonium has leached out and, possibly reconcentrated elsewhere has not been assessed as yet.
6. **Canister Performance Allocation:** Transportation canisters and emplacement canisters are used in this design.
7. **Borehole Geometry:** The telescoped borehole geometry adopted in this design represents the largest bottom-hole diameter (i.e., 0.660 m (26 in)) that can be reliably drilled to a depth of 4 km in competent plutonic/metamorphic rock formations using standard existing equipment. The bottom 2 km uncased section of the borehole will be the disposal form Emplacement Zone. The upper 2 km cased section is the Isolation Zone of the borehole and is used to seal the borehole and isolate its contents from the biosphere. The borehole depth required to ensure long-term performance is usually site specific. It is assumed here that for the generic site considered, a 4 km depth would be satisfactory. As discussed in Section 1.3.1, many other combinations of small (< 0.254 m (10 in)) and large (> 0.508 m (20 in)) diameters, and deep (> 4 km) and very deep (> 6 km) boreholes are possible; their application and the choice of an optimum borehole configuration will be investigated in future studies.
8. **Borehole Array Spacing:** The spacing between boreholes is assumed to be 500 m. The suitability of this value must be evaluated through post-closure performance analyses based on subsurface site characteristics data. In particular, it must be selected to prevent fluid communication between different boreholes through fractures and permeable zones.
9. **Offsite Feed Form Transportation:** The plutonium metal / plutonium dioxide will be delivered to the Facility by SST in a transportation cask.
10. **Operating Basis:** Unless specified otherwise, normal Base Case operation is assumed. For the Base Case, the facility will operate 5 days/week, 8 hours/day, 250 days/year for the Surface Processing and Emplacement-Borehole Sealing Processes. The Drilling Process will operate 24-hours/day in three 8-hour shifts. The Base Case surge rate will be handled by introducing a second 8-hour shift in the Surface Processing and Emplacing-Borehole Sealing Processes and by adding a second drilling rig and crew in the Drilling Process.

11. **Generic Site:** The Deep Borehole Disposal Facility is a new facility embodying the deep borehole concept. Both the design concept and the facility site are generic. The current working assumption is that the host-rock will be a plutonic/metamorphic crystalline rock formation in a tectonically, hydrologically, thermally and geochemically stable region. It is assumed that at this generic site, a 4 km deep borehole would be sufficient to ensure long-term performance of the Deep Borehole Disposal Facility. This assumption will be evaluated for validity in future investigations.
12. **Facility Raw Water Source:** If the site is a dry site without a supply of surface water, the water is obtained from water wells drilled in the security Buffer Zone at the site itself. For a wet site, water is obtained from the local utility water supply.
13. **Regulatory Compliance and Safety Features:** The Deep Borehole Disposal Facility design presented here is intended to comply with all applicable federal, state (e.g., NRC, EPA, DOE, DOT, OSHA, NFPA) and IAEA regulations dealing with the transport, use, safeguards and security of special nuclear materials, criticality safety, underground disposal of nuclear materials, environmental safety and health, and occupational safety and health. Confinement, containment, control and monitoring safety system features mandated by the applicable regulations must be fully implemented.
14. **Design Status:** The Deep Borehole Disposal Facility Design presented here is a preliminary design based on initial work performed to date. It reflects the current state of an evolving facility design. Many important issues related to site characteristics, transport mechanisms, borehole geometry, disposal forms, canister designs, durability and selection of engineered barrier materials, drilling, emplacement and processing technologies, criticality safety, and long-term post-closure performance have not been addressed yet. As such, the facility design presented here may be modified during the design process.

Pu oxide or metal arrives in 6M/2R-like containers via SST truck at the Deep Borehole Facility. The final disposal form of plutonium includes excess Pu oxide or metal from production or recovery facilities. Each PCV holds two Pu product cans with double containment. Each Pu product can contains approximately 2.25 kg of Pu. The unloading processing is performed in an airlocked area. Confirmatory and accountability measurements are made after unpacking. Prior to being placed in emplacement canisters, the plutonium product cans are stored in a shielded storage vault in the transportation containers in which they were delivered.

Facility Design Parameters and Sensitivity to Pu-Loading

The design parameters, the capacity and size of the resulting facility, and the volumes and masses of materials must be handled by the facility are presented and discussed here. For more complete details, refer to *Wijesinghe et al. (January 15, 1996d).*

The design given here begins by assuming that, for the generic site considered, a 4 km borehole provides sufficient isolation and that the borehole is drilled to the maximum emplacement zone diameter possible with current drilling technology. This yields the maximum possible emplacement zone volume for a 4 km deep borehole. This assumption will be evaluated through detailed performance assessment and systems optimization analyses in the future. The borehole completion resulting from this assumption is given in Table 1.4-1. Next the number of primary containment vessels (PCVs) per emplacement canister, the spacing between PCVs within the emplacement canister, the emplacement canister dimensions, the number of emplacement canisters per canister string are decided upon on the basis of internal and external sealing requirements, the required canister strengths, installation clearance requirements, the need for inter canister string seals, and the emplacement zone height. From the volumes established in this way, it is possible to determine the volume and the mass of the SFM feed that can be accommodated in the emplacement zone of a single borehole. Using this mass of Pu feed form, the Pu linear loading, and the mass of Pu disposed of in a single borehole is computed. In Table 1.4-1, from purely volumetric considerations, the mass of Pu feed form that is emplaced, and the volumes of rock removed by drilling, sealant for encapsulating the primary containers within the emplacement canisters, grout for sealing the emplacement zone, and the grout needed to seal the isolation zone are given for a single borehole. An important observation about this canistered design option (and most other canistered designs) is that the volumetric emplacement efficiency of the feed form, defined as the fraction of the emplacement zone volume occupied by the primary containers, is very low and amounts to only 1.56%.

The number of boreholes required to accommodate the 50 t of plutonium is then computed. The resulting fractional number of boreholes is rounded down if less than 15% of the disposal capacity of the last borehole is utilized; otherwise it is rounded up, and another borehole is drilled. Adjustments are then made to the calculated volume of sealants, grouts etc. to account for partial filling of the last borehole with emplacement canister strings.

Finally, and most importantly, the criticality coefficient is calculated for each emplacement configuration and Pu-loading for a number of worst case scenarios to evaluate criticality safety. These calculations include scenarios such as complete permeation of all void volumes in the borehole with brine bearing dissolved plutonium at the solubility limit at typical temperature and pH conditions. It was found that the dissolved plutonium contained in brine was far too small to have any effect on criticality. Also, it must be anticipated that a few hundred years after emplacement, all canisters will have disintegrated, and the plutonium in the product cans may be disrupted into smaller pieces. The latter scenario increases the brine content and the moderating effect of hydrogen in the brine with the result that it restricts the criticality-safe Pu-loading of the emplacement canisters.

Table 1.4-1 Deep Borehole Design Sizing Parameters

Design Parameters	Value	Unit
Geometric Parameters:		
Emplacement canister OD	0.41 (16.0)	m (in)
Emplacement canister ID	0.38 (15.0)	m (in)
Emplacement canister height	6.1 (20.0)	m (ft)
Primary container (PCV) OD	0.14 (5.5)	m (in)
Primary container height	0.51 (20.0)	m (in)
Primary container volume	0.00779	m^3
Pu/Primary container	4.500	kg
Borehole dia. (2 - 3 km)	0.91 (36.0)	m (in)
Borehole dia. (3 - 4 km)	0.66 (26.0)	m (in)
Length of canister string	152 (500.0)	m (ft)
Canister string volume	19.769	m^3
# Empl. canisters/canister string	25	
Emplacement zone height	2	km
# Canister strings/borehole	12	
# Empl. canisters/borehole	300	
Masses & Volumes:		
Empl. canister sealant density	2,000.0	kg/m^3
Emplacement canister int. volume	0.695	m^3
Empl. zone volume/borehole	1,029	m^3
Empl. zone grout vol/borehole	791	m^3
Isolat. zone grout vol/borehole	1,538	m^3
Empl.+ isolat. zone vol/borehole	2,330	m^3
Rock volume removed/borehole	3,337	m^3
Borehole drilling criterion	15.00	%
Total Pu mass to be disposed	**50.00**	t

The effect of Pu-linear-loading on the number of boreholes, and the emplacement canister interior sealant, grout and rock volumes and masses that need to be handled are given in Table 1.4-2. Two spatial arrangements of the primary canisters within an emplacement canister in a horizontal cross-section through the borehole (i.e., a single centrally placed canister or three canisters equally spaced along a circle) were considered. The axial spacing between primary canister sets is changed to vary the Pu-loading per unit length of the emplacement zone. In Figure 1.4-1, the variation of the criticality coefficient with axial spacing is given for a single centrally placed canister for dry and brine saturated canister sealants. Criticality coefficients for the 6 kg/m loading configuration with three canisters in a horizontal plane, corresponding to the present deep borehole disposition design, are given in Table 1.4-2 and in Figure 1.4-2 for both dry and wet sealants. In this case, the configuration was substantially sub-critical. However, criticality was not investigated for the case when the canisters have disintegrated and the entire borehole cross-section is saturated with brine. This case will be evaluated in the future. The results given in Table 1.4-2 show that 50 MT of plutonium can be disposed of in 4 boreholes at a Pu-linear-loading of 6 kg/m.

Table 1.4-2 Impact of Plutonium Loading on Deep Borehole Design

Pu Linear Loading kg/m	1.33	4.00	2.00	**6.00** [1]	2.67	8.00
Primary container arrangement	1	3	1	**3**	1	3
Pri. container sets/empl. canister	2	2	3	**3**	4	4
Primary container axial spacing m	2.540	2.540	1.524	**1.524**	1.016	1.016
Primary containers/empl. canister	2	6	3	**9**	4	12
Mass of Pu/empl. canister kg	9.00	27.00	13.50	**40.50**	18.00	54.00
Mass of Pu/canister string kg	225.0	675.0	337.5	**1012.5**	450.0	1350.0
Mass of Pu/borehole t	2.70	8.10	4.05	**12.15**	5.40	16.20
# Boreholes (Exact)	18.52	6.17	12.35	**4.12**	9.26	3.09
# Boreholes (Rounded)	19	7	13	**4**	10	3
Actual Pu disposal capacity t	51.30	56.70	52.65	**48.60**	54.00	48.60
# Canister strings	222	74	148	**48**	111	36
# Emplacement canisters	5,556	1,852	3,704	**1,200**	2,778	900
# Primary containers (PCVs)	11,111	11,111	11,111	**10,800**	11,111	10,800
Total empl. canister sealant m^3	3,775	1,201	2,488	**750**	1,844	541
Total emplace. zone grout m^3	15,174	5,744	10,460	**3,164**	8,102	2,373
Total isolation zone grout m^3	29,225	10,767	19,997	**6,153**	15,382	4,615
Total empl.+ isolat. grout m^3	44,400	16,511	30,455	**9,317**	23,483	6,988
Total rock removed m^3	63,440	23,372	43,406	**13,356**	33,389	10,017
Criticality Coeff.[2] Dry Sealant	-	0.79	-	**0.80**	-	0.80
Criticality Coeff.[2] Wet Sealant	-	0.83	-	**0.83**	-	0.83

[1] Pu mass loading used in the design

[2] Criticality coefficient for dry/wet bentonite sealant inside canister and wet grout around canister in borehole

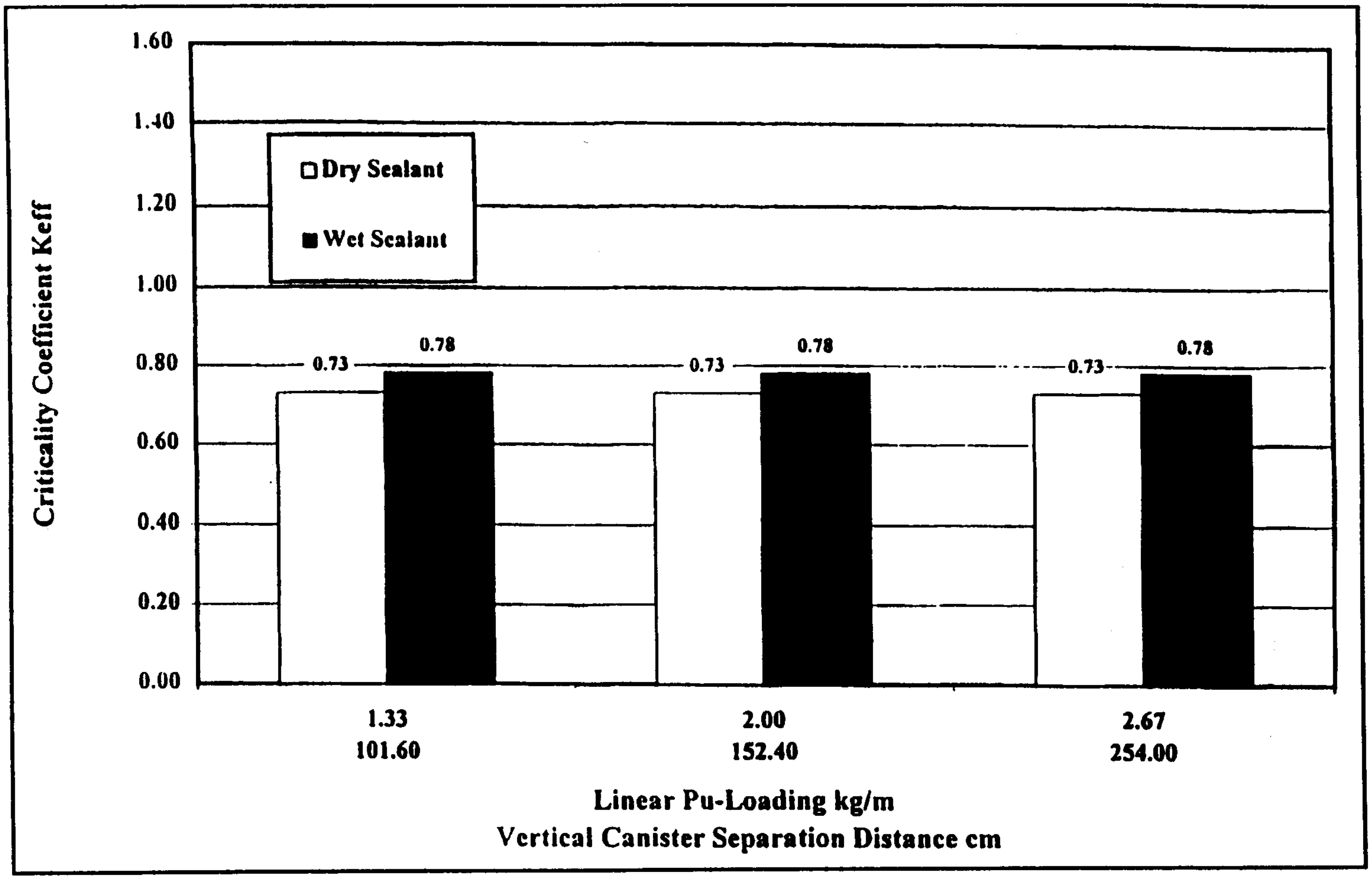


Figure 1.4-1: Criticality Analysis for One PCV in a Horizontal Plane with Sealant, Grout and Brine in the Borehole

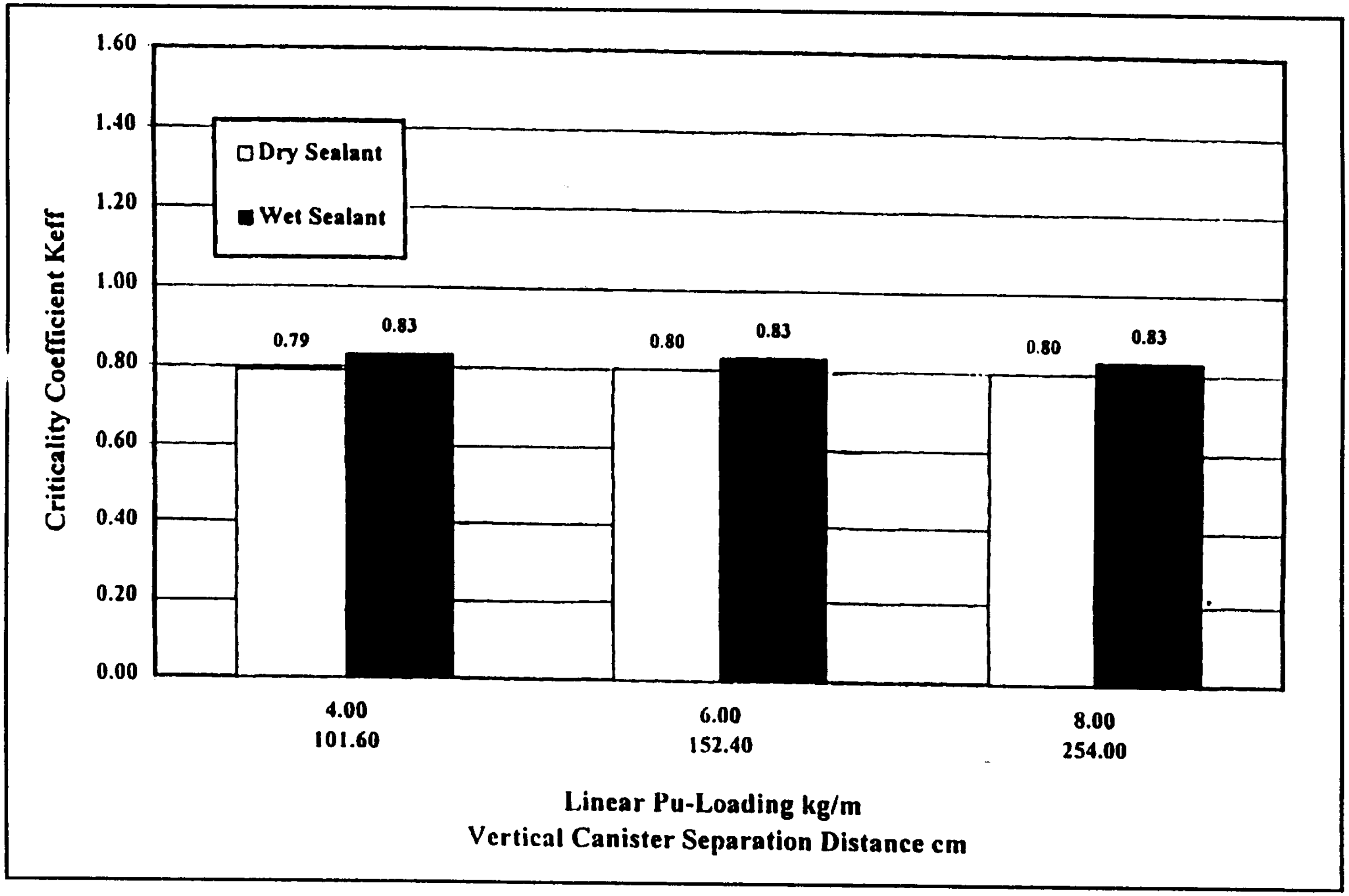


Figure 1.4-2: Criticality Analysis for Three PCVs in a Horizontal Plane with Sealant, Grout and Brine in the Borehole

1.4.1 Facility Description

The Deep Borehole Disposal Facility consists of a Surface Processing Facility for receiving the canistered disposal form, inspecting the canisters, storing them, and, finally, repackaging the disposal form in emplacement canisters; a drilling facility for drilling the borehole and casing and sealing hydraulically conductive features in the host-rock; an Emplacing-Borehole Sealing Facility for connecting together the canister modules into long canister strings, emplacing them within the borehole, and sealing the borehole; and a Waste Management Facility for treating the wastes generated by the borehole disposal operations. The functional elements of the envisaged Deep Borehole Facility are shown in Figure 1.4.1-1. In addition, there is a Support Facility consisting of the Administration, Plant Operations and Balance-of-Plant facilities. Descriptions of significant facility components are provided in Table 1.4.1-1.

The Borehole Array Area of the Deep Borehole Facility consists of the relocatable Drilling Facility, the resulting 4 km deep boreholes, a separate Emplacing-Borehole Sealing Facility to deliver the emplacement canisters downhole and, finally, to seal in place. Figure 1.4.1-2 shows a general plot plan for the Deep Borehole Disposal Facility**.**

The Site Plan of the Deep Borehole Disposal Facility given in Figure 1.4.1-3 details the layout of the facility in both the Main Facility and Borehole Array Areas. It also shows the access routes for off-site transportation, and the two on-site transportation routes for trucks bearing plutonium. Figure 1.4.2-3 shows the Security Boundaries and Buffer Zone surrounding the Facility and delineates the four boreholes required by this design.

The Deep Borehole Disposal Facility will be designed with site-specific design criteria to comply with DOE orders and applicable NRC regulations covering the design, construction, and safety of non-nuclear reactor plutonium facilities. The facility will incorporate the safety, security and environmental protection considerations as required by DOE orders and applicable NRC and EPA regulations. The facilities will be designed for earthquake, fire, wind and flood safety. In addition, the entire facility will be designed to include the basic controls for assuring nuclear criticality safety.

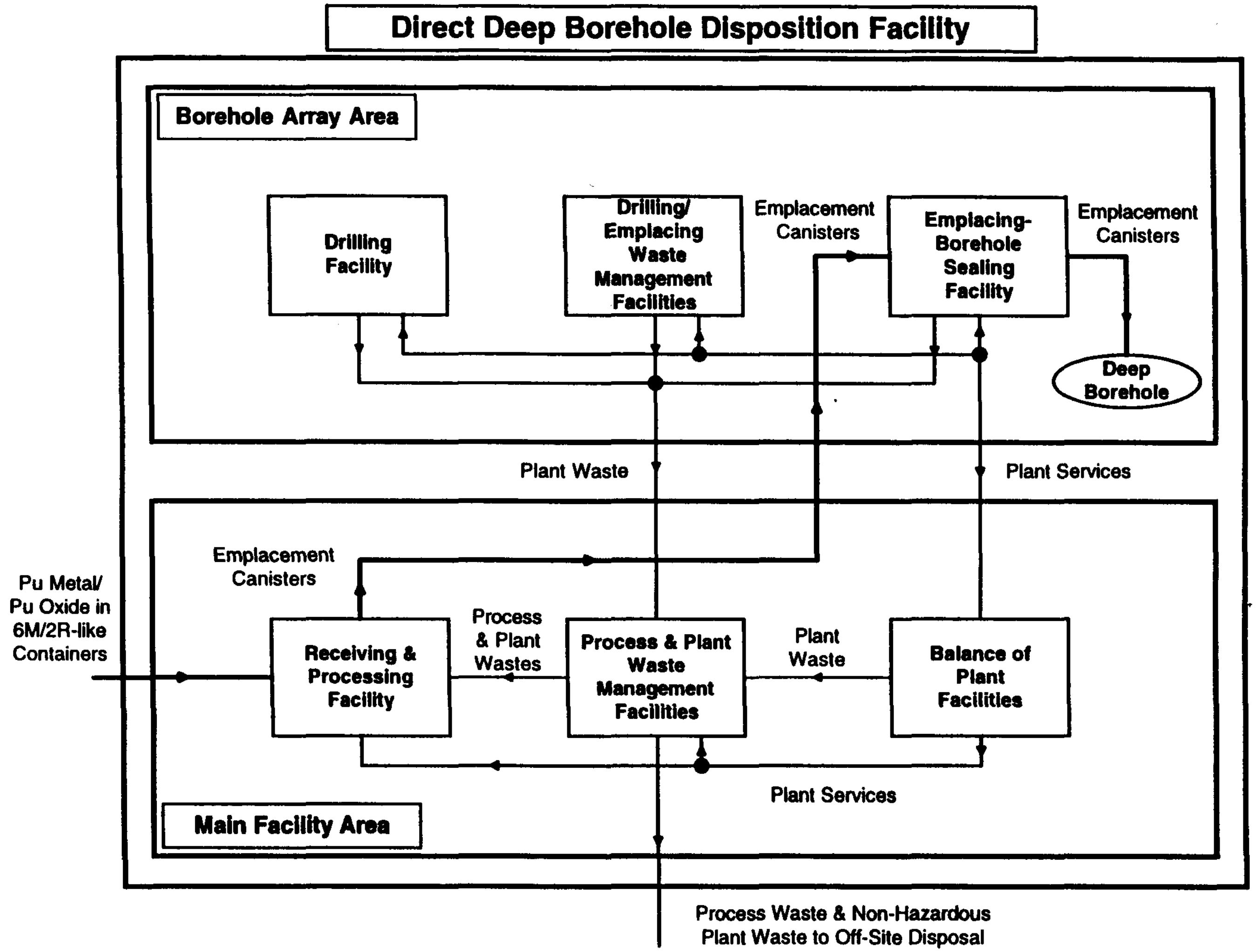


Figure 1.4.1-1: First Level Borehole Facility Process Flow Diagram

Table 1.4.1-1: Deep Borehole Disposal Facility Data

Building Name	Building Code	Footprint (m^2)	Number of Levels	Special SNM Materials	Construction Type
Main Area Facilities:					
Administration	M-1	1,394	1	None	Light Steel
Personnel Services	M-2	1,394	1	None	Light Steel
Medical Center	M-3	929	1	None	Light Steel
ES&H	M-4	929	1	None	Light Steel
Security Center	M-5	1,858	1	None	Light Steel
Security & Fire Training Area	M-6	929	1	None	Open Area
Fire Station	M-7	929	1	None	Light Steel
Warehouse & Maintenance	M-8	2,323	1	None	Light Steel Frame
Receiving and Processing	M-9	5,295	2	SNM	Concrete
Plant Utilities	M-10	929	1	None	Masonry
Process Waste Management	M-11	1,742	1	SNM, SNM Wastes	Concrete
Drilling & Emplacing Operations Center	M-12	929	1	None	Light Steel Frame
Electrical Substation	M-13	650	1	None	Concrete Pad
Plant Waste Management	M-14	650	1	None	Light Steel Frame
Employee Parking	M-A	2,323	1	None	Asphalt
Laydown Area & Storage Yard	M-B	5,574	1	None	Open Area
Truck Parking	M-C	929		None	Asphalt
Truck & Rail Security Portals	M-D	28	1	None	Masonry
Passenger Vehicle Portal	M-E	47	1	None	Masonry
Cooling Tower	M-F	743		None	Steel
Gas Stack	M-G	37		None	Steel
Drilling Facilities:		46,450			
Drill Rig	D-1	1,858	1	None	Steel Frame
Drilling Shift Office Trailers	D-2	1,828	1	None	Trailer
Cement Trucks	D-3	139	1	None	Vehicles
Cement & Water Storage Tanks	D-4	465	1	None	Steel Tanks
Compressor Station	D-5	47	1	None	Concrete Pad
Potable Water Tank	D-6	47	1	None	Stainless Steel
Drilling Fluid Tanks	D-7	465	1	None	Steel
Treated Water Storage	D-8	3,716	1	None	Steel,Concrete
Generator Truck	D-9	70	1	None	Vehicle
Drilling & Emplacing Storage Yard	D-A	929	1	None	Concrete

Table 1.4.1-1: Deep Borehole Disposal Facility Data (Continued)

Building Name	Building Code	Footprint (m^2)	Number of Levels	Special SNM Materials	Construction Type
Drilling Wastewater Treatment	D-B	186	1	None	Steel Frame
Drilling Mud Pits	D-C	7,432	1	None	Earth
Mud & Water Pumps	D-D	47	1	None	Concrete Pads
Pipe Storage	D-E	186	1	None	Packed Earth
Emplacing Facilities:		46,450			
Emplacing Crane	E-1	1,858	1	None	Steel Frame
Radiation Monitoring	E-4	93	1	None	Light Steel Frame
Containment Structure	E-5	279	1	SNM Waste	Heavy Steel Enclosure
Emplacing Sub-Base	E-6	186	1	SNM Waste	Steel Frame
Emplacing Shift Office Trailers	E-7	1,858	1	None	Trailer
Storage Tanks	E-8	`186	1	SNM Waste	Steel
Compressor Station	E-9	47	1	SNM Waste	Concrete Pad
Generator Truck	E-10	70	1	SNM Waste	Earth
Cement Trucks	E-11	139	1	SNM Waste	Earth
Potable Water Tank	E-12	47	1	SNM Waste	Steel
Pipe Handling Crane	E-13	139	1	SNM Waste	Packed Earth
Process Water Storage	E-14	93	1	SNM Waste	Steel Tank
Waste Monitoring & Testing Station	E-15	47	1	SNM Waste	Light Steel Frame
Entrance Security Portal	E-16	9.3	1	None	Masonry

1.4.2 Generic Site Description

The Deep Borehole Disposal Facility site described here is a generic site at a *hypothetical* geographical location in the United States called Deep Rock, USA. In developing this generic site description, the characteristics of an ideal site have been used for guidance to arrive at a realistic description of a site that can be found in a number of areas in the continental United States. Site information is provided at a level of detail sufficient to make an approximate assessment of the environmental impact at the site. The data provided includes the geographical and topographical features of the area, the subsurface geology and hydrology, the climate, the levels of seismic activity and wind speeds, the population densities and population centers, rail, road and air traffic access ways, and a site map. Detailed quantitative information regarding the surface and subsurface characteristics of the site are given in the PEIS Data Report for this Borehole Disposition Alternative in *Wijesinghe et al. (January 15, 1996d).* The Deep Rock site, shown in Figure 1.4.2-1, is located in a rural area surrounded by farmland and characterized by low, rolling terrain. The topography of the area is rather flat with a maximum topographic relief of 25 m over the area shown in Figure 1.4.2-1.

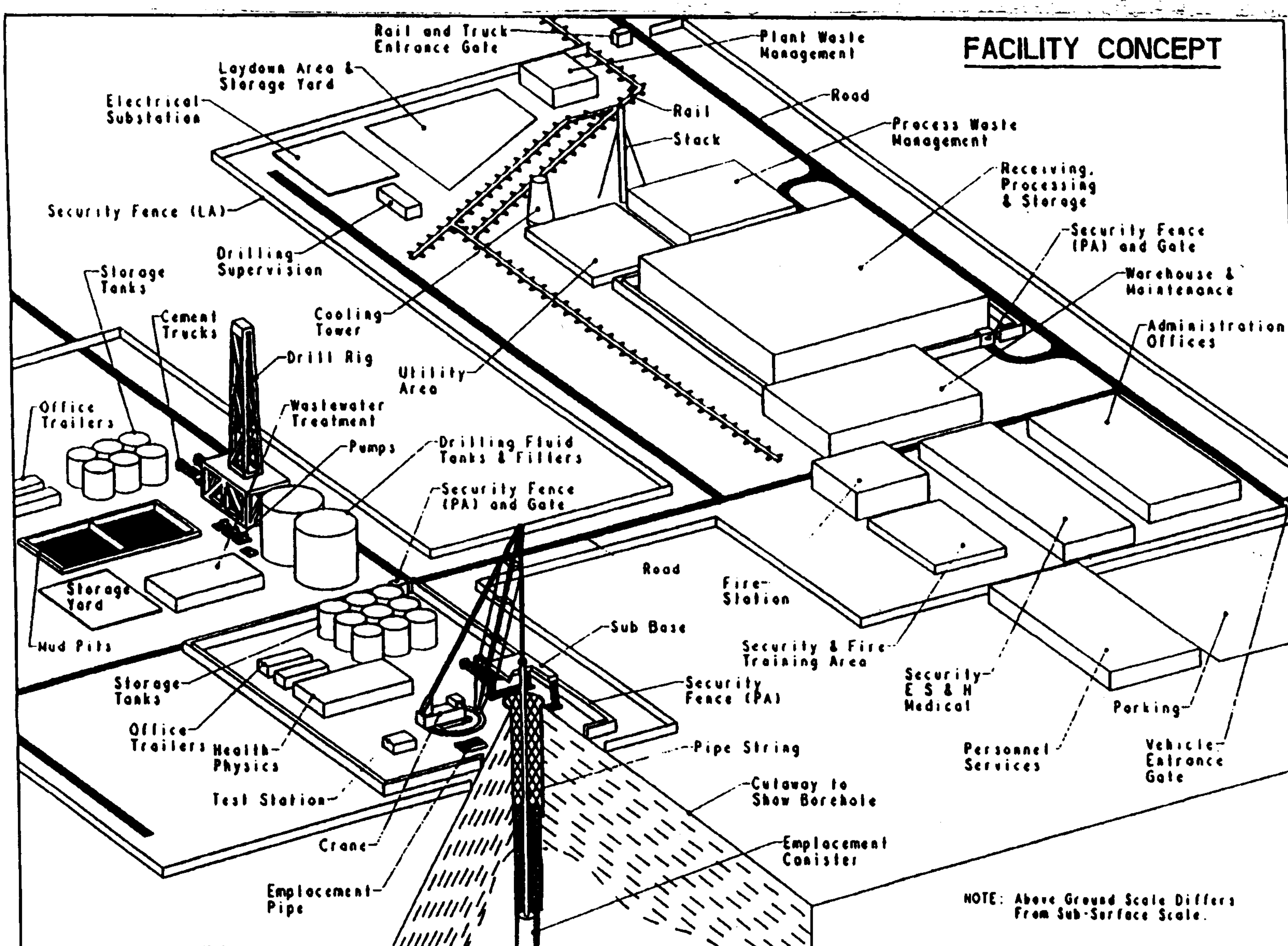


Figure 1.4.1-2: Perspective View of the Deep Borehole Disposal Facility

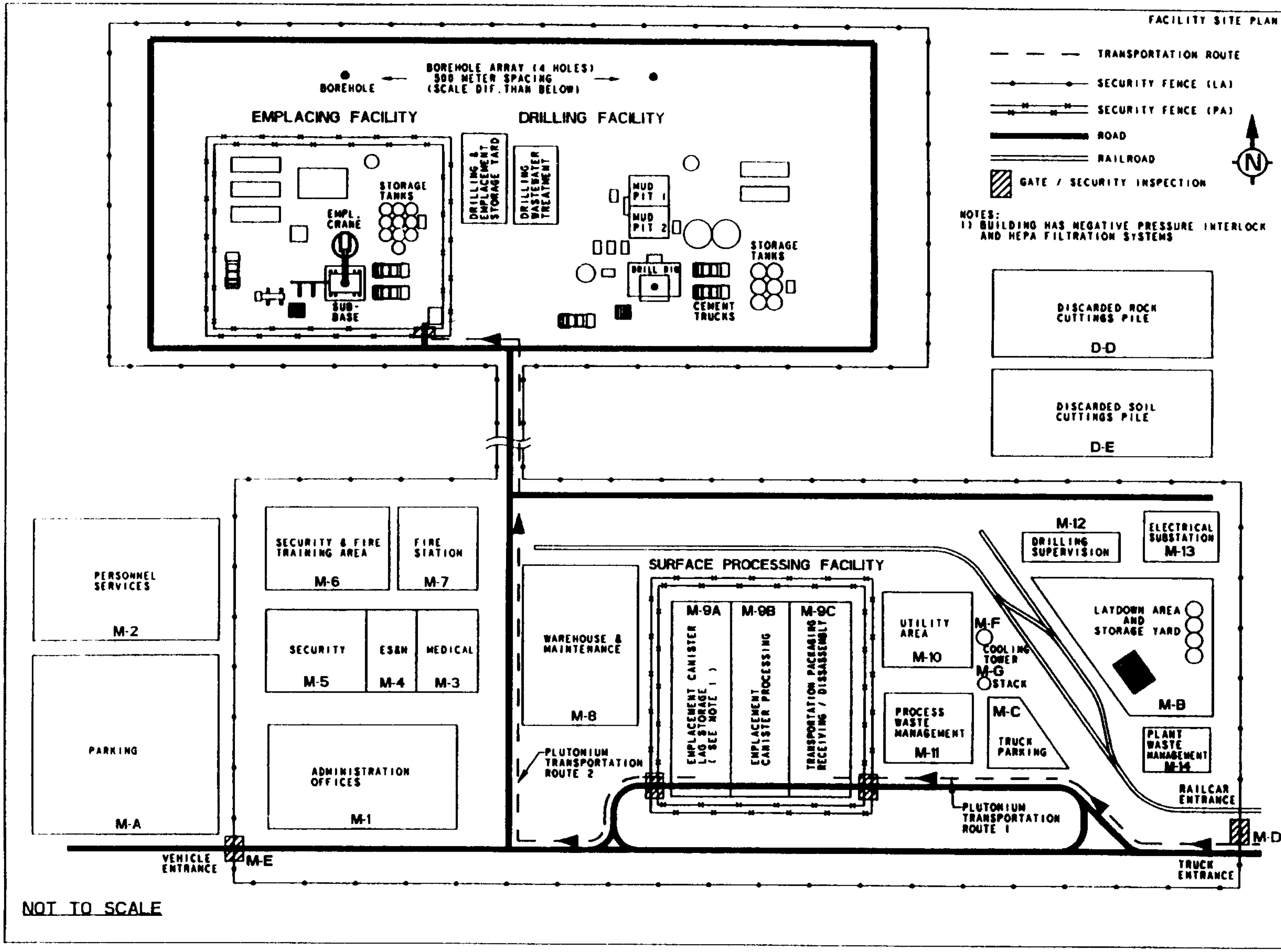


Figure 1.4.1-3: Deep Borehole Facility Site Plan Detail and Plutonium Transportation Routes

Site Map and Deep Borehole Facility Land and Road Access Requirements

The Site Map of the Deep Borehole Disposal Facility is given in Figure 1.4.2-3. It shows the Security Boundaries and Buffer Zone surrounding the facility. It also shows the 4 boreholes required by this design variant and the spacing between the boreholes in the array. Detailed descriptions of the facilities are given in Section 1.4.1. Figure 1.4.1-3 shows in more detail the layout of the facility in both the Main Facility and Borehole Array areas. It also shows the access routes for off-site transportation, and the two on-site transportation routes for trucks bearing Plutonium.

The footprint areas of the Deep Borehole facilities are listed in Table 1.4.1–1, Facilities Data. The Deep Borehole Disposal Facility requires approximately 2,041 hectares (5,044 acres) of land for the entire facility and its 1.6-km (1-mile) wide Buffer Zone. Of this area, 32 hectares (78 acres) is occupied by the Main Facility, 25 hectares (62 acres) by the Borehole Array, and 1,873 hectares (4,628 acres) by the Buffer Zone. The total land area disturbed during the operation period is approximately 56 hectares (139 acres).

During the Closure period, the main facility area of the Deep Borehole Disposal Facility will be restored and returned to natural conditions. During closure activities the Deep Borehole Disposal Facility requires the same land area as during its operation phase and the total disturbed land area will be the same at approximately 56 hectares (139 acres).

During the Post-Closure period the Borehole Array area of 25 hectares (62 acres) will be declared a limited access area indefinitely, and a 1.6-km (1-mile) Buffer Zone of 1,358 hectares (3,355 acres) may also be declared off-limits. Thus, the Borehole Array area will require approximately 1,383 hectares (3,417 acres) to be declared off-limits. The total disturbed land area during the Post-Closure period will be the approximately 0.1 hectare (0.25 acre) occupied by the 15 m x 15 m (50 ft x 50 ft) concrete security and anti-water infiltration caps installed above the 4 boreholes.

During the Construction Period, the Deep Borehole Disposal Facility requires approximately 4 hectares (10 acres) of land for construction laydown and warehousing and 2 hectares (5 acres) for construction parking.

A minimum of one mile two-lane paved road and railroad spur track will have to be constructed to the Deep Borehole Disposal Facility site for workers transportation and material and equipment delivery. The length of the road connections depends on the specific site.

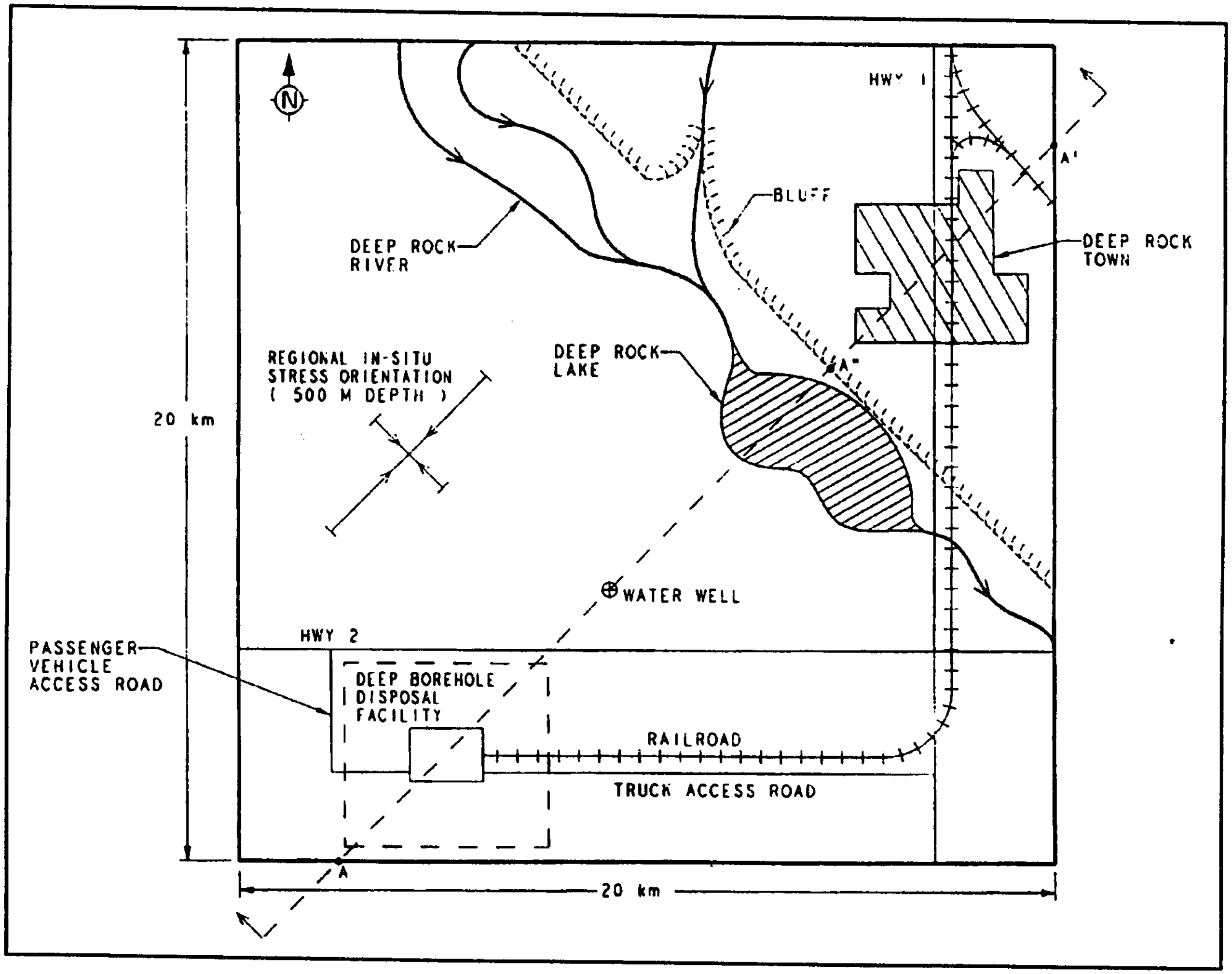


Figure 1.4.2-1: Geographic Generic Site Area Map of Deep Borehole Disposal Facility

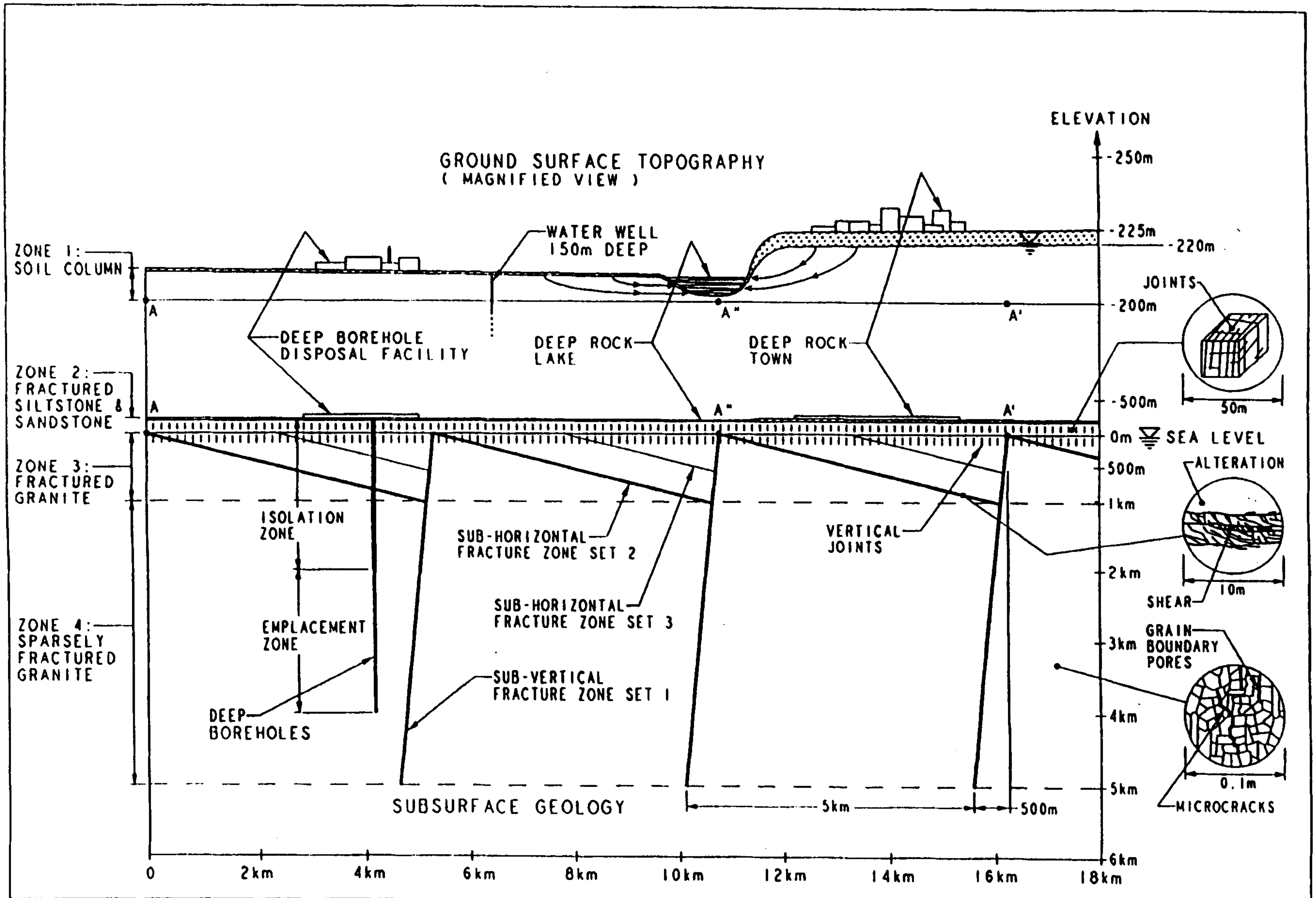


Figure 1.4.2-2: Geologic Cross-Section on A-A' (in Figure 1.4.2-1) Showing Hydrogeologic Features at the Generic Deep Borehole Disposal Facility Site

1.4.3 Facility Operation

The Deep Borehole Facility accepts plutonium feed materials directly as metal, and plutonium dioxide. The plutonium feed material is placed in deep competent rock with ancient, nearly dormant brine. The plutonium feed is received, inspected, and stored at the Surface Processing Facility pending placement into large canisters and transportation on-site to the Emplacement Facility. Deep boreholes are drilled to a depth of about 4 kilometers and cased from the surface to about 2 kilometers. The Emplacement/Sealing Facility is located near the boreholes to receive the canister strings, emplace them to depth, and seal them in place to minimize brine intrusion and to prevent criticality.

The facility will operate 5 days/week, 8 hours/day, 250 days/year for the Surface Processing and Emplacement-Borehole Sealing Processes. The Drilling Process will operate 24-hours/day in three 8-hour shifts. The surge rate will be handled by introducing a second 8-hour shift in the Surface Processing and Emplacing-Borehole Sealing Processes and adding a second drilling rig and crew, if needed, in the Drilling Process.

The process flow diagram for the Surface Processing Facility is shown in Figure 1.4.3-1 together with its waste flow diagram. After recovery from storage, the undamaged transportation canisters are assembled into larger units by placing them within an emplacement canister and encapsulating them in place with an appropriate sealant by vacuum impregnation and, finally, using a mechanical seal for the top closure plate. At the Emplacement Facility, these emplacement canisters are threaded together to form a 152 m (500 ft.) long canister string and the spaces between the individual emplacement canisters are filled with sealant.

A separate relocatable Emplacing-Borehole Sealing Facility will emplace the canisters in the boreholes in the sequence in which the boreholes are drilled. Since the duration of emplacement operations depend on the schedule of delivery of plutonium feed material to deep borehole facility, and are expected to take longer than the drilling operations, several Emplacing and Borehole Sealing Facilities may be needed for each Drilling Facility. First, the 6.1 m (20 ft.) canister sections will be combined into larger 152 m (500 ft.) long canister string by threading the current canister section to the top of the canister string that is held is place within the borehole with its top exposed above the borehole entrance. The canister string is then lowered into the borehole and emplaced as a single unit. Emplacing includes grouting of the spaces between canister strings as well as between the canister strings and the borehole wall with specially formulated grouts. The solid aggregate in the concrete is designed to prevent settlement of the canister strings under stress before the concrete has adequately cured and acquired strength. The primary feed to the Emplacing-Borehole Sealing Process are the emplacement canisters prepared in the Surface Processing Facility. Approximately 12 canister strings, each containing 25 canister modules (each 6.1 m (20 ft.) long), can be accommodated in one borehole with a 12.2 m (40 ft) hydraulic and transport seal between canister strings.

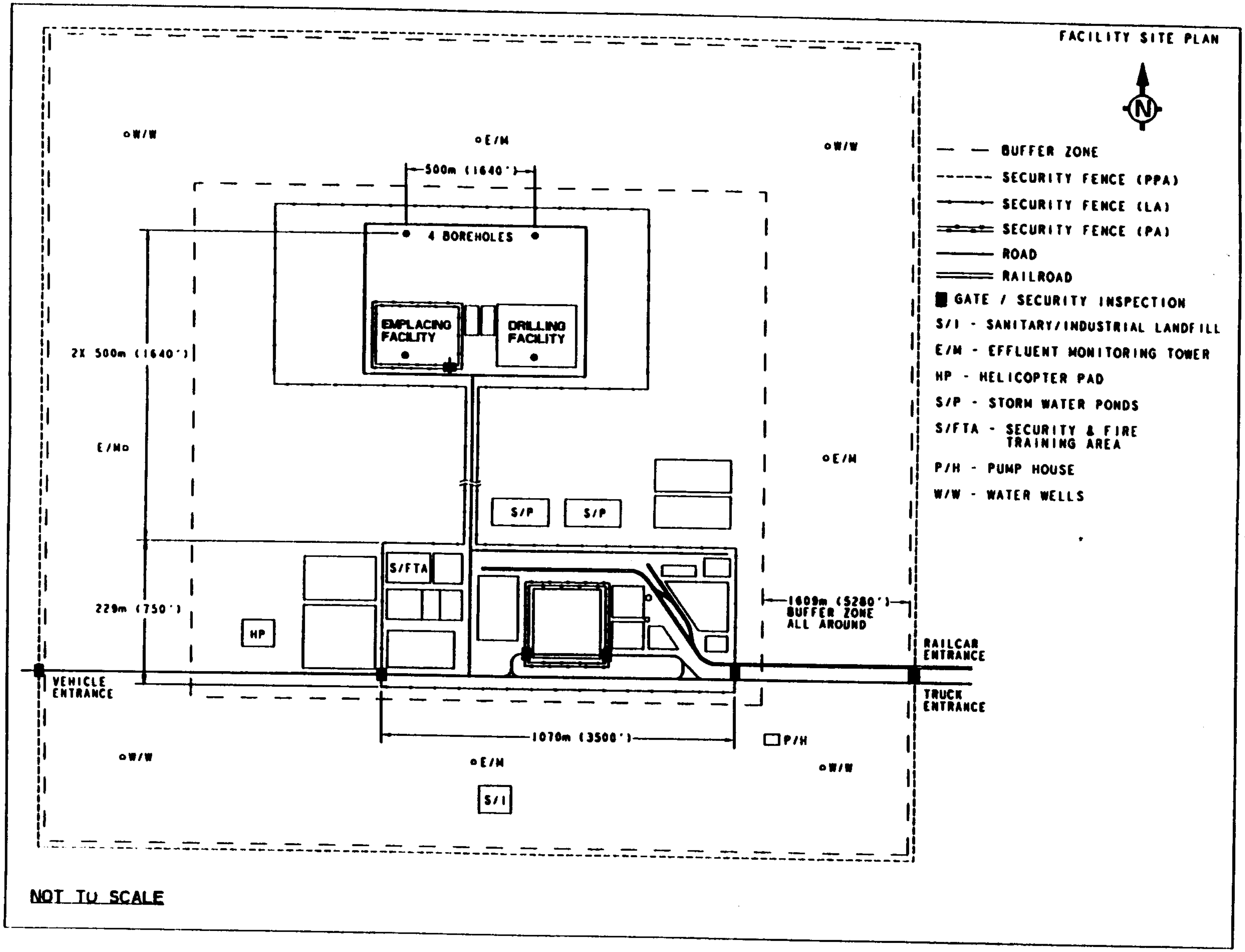


Figure 1.4.2-3: Deep Borehole Disposal Facility Site Map (Including Security Boundaries)

The Emplacing-Borehole Sealing Facility will install periodic hydraulic and transport seals within the emplacement zone between canister strings and at the top of the emplacement zone. It will also backfill the borehole to the surface with sealing grout and will finally install a security and anti-water infiltration concrete cap at the top of the borehole at the ground surface.

Approximately 1,111 transportation canisters and 124 emplacement canisters will be processed annually by the Surface Processing Facility. Each emplacement canister will contain 40.5 kg of plutonium. The feed rate of plutonium / plutonium dioxide disposal form to the Surface Processing Facility is the equivalent of 5 t/year of plutonium. During surge operation at 10 t/year of plutonium, these rates will be doubled.

Drilling operations involve the preparation of the drilling mud with appropriate additives, maintaining the mud column at the proper density, pumping water out when needed to control water inflow from conductive aquifers and fractures, using mud additives and plugging back these features to control the inflows, and installing steel casing and cementing behind the casings as the drilling progresses. The borehole will be drilled using technology that has been used extensively in the petroleum industry. The drilling system consists of a drill rig (or derrick) which is used to lower and raise the drill pipe and the drill bit in the borehole, and the associated drilling mud and fluids handling support facilities. Very large quantities of materials such as drilling muds, grouts, casing, and chemical additives will be required for operating the Drilling Facilities**.** The drilling process requires the circulating water and drilling muds to be periodically replaced by fresh mud, water and chemicals which include polymers, soaps, and pH control additives. The estimated time required to drill one borehole is from 10 to 11 months using three 8-hour shifts a day by rotating three crews.

1.4.4 Waste Management

A Process Waste Management Facility is provided in the Main Facility Area for treating the Process Rad-Wastes and Process Wastewater in the Borehole Array Area. These wastes are generated by the borehole disposal operations. In addition, a Plant Waste Management Facility is provided in the Main Facility Area to handle Utility and Sanitary Wastes.

1.4.5 Intrasite Transportation

Currently, the transportation of radioactive material onsite at a DOE facility is not covered by Federal Regulations. Regulations will be developed for the transportation of Plutonium. The transportation of plutonium in waste material is controlled by DOE-EH.

The movement of the plutonium feed material and the plutonium in its final disposal form on-site does not represent a significant potential impact to the offsite environment because the disposal form arrives onsite in hermetically sealed transportation inner containment vessels which are not opened onsite. The transportation

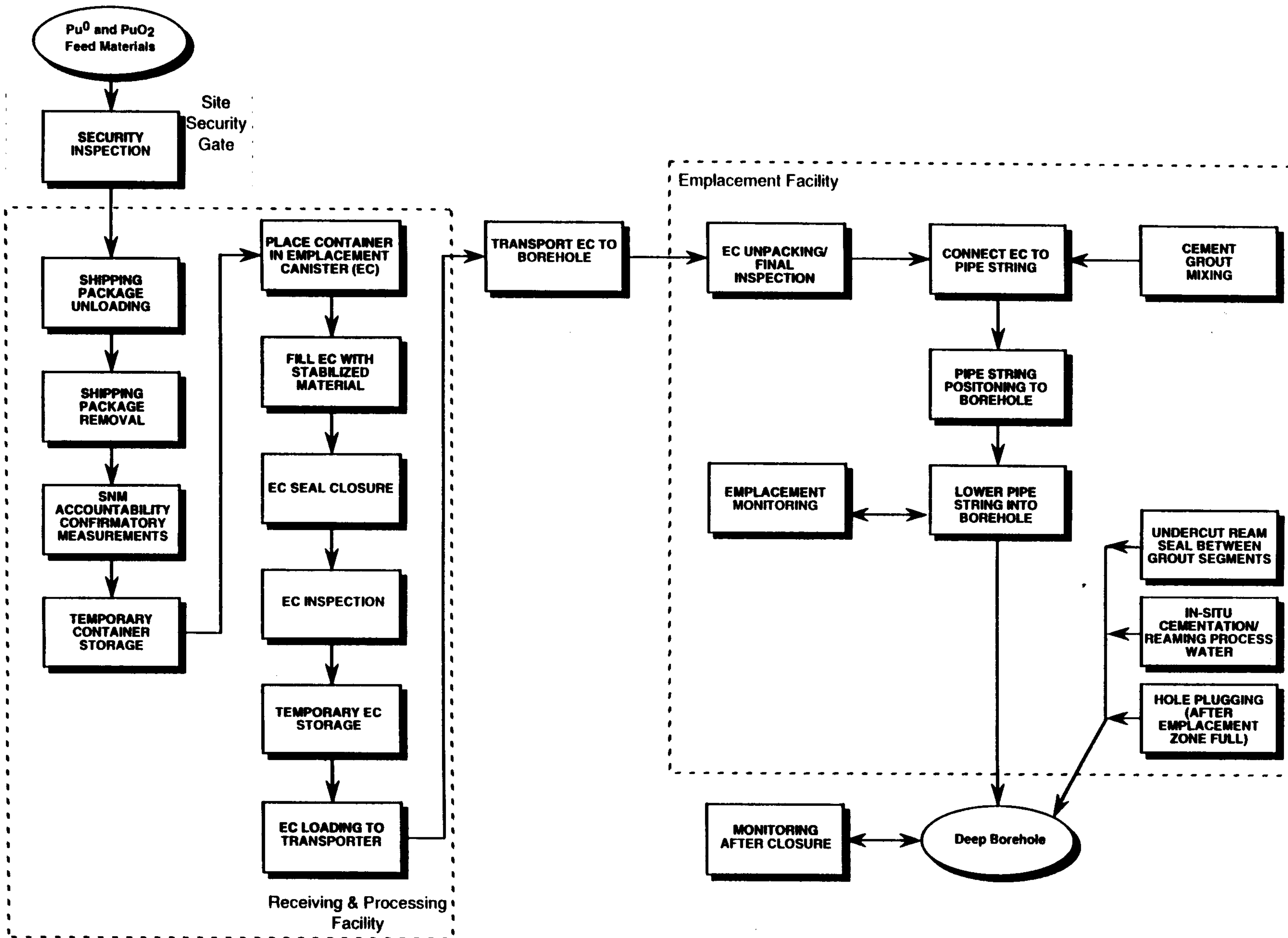


Figure 1.4.3-1: Deep Borehole Disposal Facility Plutonium Process Block Flow Diagram

routes used and procedures adopted to mitigate any accident related potential impacts are addressed below.

Feed Form Transportation to the Surface Processing Facility

In this Deep Borehole Disposal Option, the feed material is in the form of Pu / PuO_2 within specification 2R inner containment vessels, approximately 14 cm (5.5 in.) in diameter x 50.8 cm (20 in.) high, which are processed at an off-site facility. At a 5 t/year Plutonium equivalent disposal rate, 1,111 transportation packages per year will arrive at the Surface Processing Facility. This feed material will be delivered to the Surface Processing Facility in DOE-approved inter-facility transportation trucks. No special safety or security requirements beyond those applied to off-site inter-facility transportation are required for on-site transit of these trucks from the site entrance to the Surface Processing Facility along the route identified as Plutonium Transportation Route 1 in the Onsite Transportation Map.

Disposal Form Transportation to Emplacing-Borehole Sealing Facility

Transportation canisters that arrive at the Surface Processing Facility are placed in larger emplacement canisters (6.1 m (20 ft) in length) and sealed with sealants and mechanically-threaded closure heads. These emplacement canisters are required to be transported by truck to the Emplacing-Borehole Sealing Facility along the route identified as Plutonium Transportation Route 2 in Figure 1.4.1-3. DOE-approved intrafacility (onsite) transportation trucks, equipped with special canister handling fixtures will be used. These enclosed trucks will conform to site environmental, Materials Control and Accountability (MC&A), and Safeguards and Security (S&S) standards.

1.4.6 Safeguards and Security

The domestic safeguards and security program is designed to ensure that surplus fissile materials, which are converted into long-term disposition forms, meet security objectives. The vulnerabilities, designs, technologies, and operations associated with Safeguards and Security are interrelated in many areas relative to physical protection, nuclear materials control and accountability (NMC&A), and international safeguards containment and surveillance (C/S).

Safeguards and Security (S&S) helps guarantee that sensitive fissile material is not diverted from the intended disposition process, that the amount of Plutonium delivered to the site - within acceptable physical measurement parameters - will be accountably disposed, and that the process satisfies international (IAEA) controls and standards of verifiability. Aspects of S&S needs/requirements, more detailed than provided here, may need to be determined by a site-specific vulnerability threat assessment (VA).

Safeguards and Security Requirements Related to Proliferation Resistance of the Direct Pu/PuO_2 Disposal Option

The facility is projected to sustain a disposal rate per year of 5 t of Pu/PuO_2 product with a surge rate of 10 t/yr. On a per day basis, the facility must handle a minimum of 20 kg of Pu/day and double this rate during surge operation. In addition, the Facility requires a 1-month inventory (417 kg) of Pu/PuO_2 material in storage for processing operations. At the Receiving Facility, the material will be received in 6M/2R-like transportation packages each containing 2 product cans and a total of 4.5 kg of plutonium encapsulated in a special sealant which fills the PCVs. Here, each 6M package will be opened, inspected and stored. Subsequently, batches of nine PCVs will be placed and sealed within each 40.6 cm (16 in.) diameter, 6.1 m (20 ft) long emplacement canister each of which will contain 40.5 kg of plutonium. Twenty-five emplacement canisters will be transported in smaller batches to the Emplacing Facility where they will be threaded together into a single canister string (containing a total of 1012.5 kg of plutonium) which is lowered into the borehole and sealed in place. These figures represent the plutonium flow rates in the areas where handling, interim storage and disposal operations are carried out.

DOE Orders set rigid guidelines for determining Category I, II, III, and IV materials when Pu is the attractive element. Each sample category is defined by an "attractiveness level" which grades the material against a set of criteria associated with its material form and/or elemental purity, and a "kg quantity level" which is simply a measure of the mass of Pu present in the sample. The Category assigned to a collection of Pu-ladened materials directly determines their security protection level. High-grade Pu materials, without regard to form, are identified as Category I or II materials and require the highest level of protection if they exceed an aggregate Pu mass of 2 kg. From the presentation in the preceding paragraph, these materials and the quantities involved are clearly Category I or Category II materials (DOE Order 5633.3A) and, therefore, require the highest level of protection.

The issue of protection levels for Pu/PuO_2 direct disposal forms can be considered from another perspective as well. The term "Spent Fuel Standard" was used by the *National Academy of Sciences (1994)* in their study of the management and disposition of excess weapons plutonium. In brief, the NAS study suggested that Pu disposal forms should be '...rendered at least as proliferation resistant as the Pu existing in commercial spent fuel.' and stated that '...deep boreholes represent a class of options that go a long way towards eliminating the proliferation risks posed by excess weapons plutonium...'. To establish a framework for selecting plutonium disposition options which would possess a high degree of proliferation resistance, the *National Academy of Sciences (1994)* reviewed a number of options and concluded that the national objective should be to make the surplus weapons-grade "plutonium roughly as inaccessible for weapons use as the much larger and growing quantity of plutonium that exists in spent fuel from commercial reactors," a state they defined as the *Spent Fuel Standard.* The Department of Energy (DOE) has enhanced this statement by defining the *DOE Spent Fuel Standard* as "a concept to make the plutonium as unattractive and inaccessible for retrieval and weapons use as the residual plutonium in the spent fuel from commercial reactors*" (DOE, July 17, 1996).* Because the Pu/PuO_2 direct disposal form is a concentrated non-immobilized form of Plutonium, it does not possess any proliferation resistance attributable to the disposal form itself. Clearly, the principal means by which the Deep Borehole Disposal concept satisfies the need for proliferation resistance is through making the material physically inaccessible. Thus, in applying the Spent Fuel Standard, to this Immobilized Deep Borehole Disposition Alternative, the Standard is more broadly interpreted as in the DOE Spent Fuel Standard to include the physical inaccessibility to all except the host country in possession of the site and high cost of physically retrieving the disposed material.

The emplacement scheme and the potential above-ground residence time of large quantities of encapsulated Plutonium closely replicates conditions of past nuclear device emplacements at the Nevada Test Site. Lengthy historical experience with successful protection and adequate Safeguards and Security controls of these activities suggest confidence that the Pu/PuO_2 direct disposal emplacement activities can be securely executed. In summary, when viewed from the perspectives of both the DOE regulations and the protection standards derived from the NAS study, at this time the Safeguards and Security requirements for this direct disposal alternative cannot be significantly moderated or relaxed below those stated above.

1.4.6.1 Physical Security System Requirements and Facilities

Programmatic activities shall be conducted within security areas designated as (1) Property Protected Access Areas (PPA), (2) Limited Access Areas (LA), and (3) Protected Access Areas (PA). A site plan noting these areas is shown in Figure 1.4.2-3.

Operations involving the plutonium disposal form in the Surface Processing Facility must be performed in a Material Access Area (MAA) which is hardened for security purposes. The MAA and facilities supporting MAA operations are located in a PA. Also, the Emplacement and Borehole Sealing Facility which later receives the disposal form is also within a PA. Each PA is secured with a double fence and intruder detection systems. The PA and operations involving classified materials are contained within the LA. The PPA surrounds the LA and includes the buffer zone around the facility. The passenger vehicle parking and personnel services (e.g. cafeteria, training center) facilities are located outside the LA but within the PPA.

The Security Center will contain the Access Control and Monitoring Center for safeguarding the main facility area and the borehole array area. This facility will be manned 24-hours a day. The features provided for physical protection of the site include site fencing, intruder detection devices, site lighting and closed circuit remote viewing systems, communications systems, personal access/egress control systems, guardhouses and vehicle control stations (rail, truck and passenger vehicles). The PA and LA area fences of the site will be lighted at night, and be protected by intruder alarm systems and remote surveillance capabilities 24 hours a day. Manned entry portals provide access to the site.

The Security Processing - Employees/Visitors Center in the Personnel Services building in the PPA zone will serve as the initial point of entry for plant visitors. Functions performed in this area include badge and pass, security office, file room, visitor control room and visitor orientation rooms. Space is provided for badging and dosimeter distribution for plant employees.

Regular access to the PPA of the facility by pedestrians and vehicles will be through the West gate where a guardhouse and access control facility is located. Visitors will be routed to the Security Processing - Employees/Visitors Center for clearance, badging and/or escort. Access to the LA of the facility will be through the West gate at the LA perimeter. Additional manned access control booths are provided for pedestrian and vehicular traffic to the PA areas.

Rail and truck access to the facility will be through the East gate at the combined perimeter of the PPA and the LA at that location. A guardhouse and an access control facility are provided at this entrance. As shown in the Site Plan, the entire borehole array area is located within the LA while the Emplacing-Borehole Sealing Facility is provided the additional security of a PA fence, guardhouse and an appropriate access control facility for both pedestrians and vehicular traffic.

Provisions are made for secure storage areas, four levels of badging for access control, key control, communications, protective forces, employee training, emergency planning and annual surveys.

1.4.6.2 Materials Control and Accountability

The material control and accountability (MC&A) program includes a system of checks and balances sufficient to detect and deter the unauthorized diversion or removal of special nuclear material from its authorized location and provide assurance that nuclear materials are in their authorized locations and are being used for authorized purposes. The facility's nuclear MC&A program, consistent with a graded materials safeguards and security program encompasses the systems and measurements necessary to track nuclear material inventories, control access, provide timely detection capability for loss and diversion of nuclear materials, and assure the integrity of the systems and measurement-in-place.

The material control and accountability system with nondestructive assay and computer systems includes bar code readers, scales, nondestructive assay devices, tamper-indicating item devices (TIDs), and computers. MC&A is applied to every process transfer point that involves plutonium material. Also, a SNM physical inventory is performed every 6 months in accordance with DOE Order 5630.2.

It is expected that the amount of nuclear material transported to the site, minus any amount held captive in waste-stream residues from processing activities, will equal the amount of material deposited in the site's borehole. An integrated site material balance system must be set in place to insure that this balance is accomplished and available for verification. Measurement systems for the determination of nuclear materials received, diverted through waste streams, or otherwise disposed must be provided as an integral component of the material accounting activity.

The Borehole Disposal Facility will be subdivided into Material Balance Areas (MBAs) for plutonium control and accounting. This covers both the Surface Processing and Emplacing-Borehole Sealing Facilities. The Receiving, Processing and Process Waste Management Buildings together form a Material Balance Area (MBA). The plutonium receiving area will satisfy all physical security requirements as described in DOE Order 5632.1C and DOE M5632.1C-1. When plutonium is classified because of configuration/ content, etc., it shall receive the physical protection required by the highest level of classification appropriate for its potential military application. The amount of nuclear material entering this MBA complex is determined by shipping records and may be validated by direct measurement.

1.4.6.3 IAEA Safeguards Requirements

The International Atomic Energy Agency (IAEA) is responsible for independently verifying that significant quantities of nuclear material have not been diverted for unauthorized uses. The primary goal of the IAEA is to detect the theft or diversion of one "significant quantity" of SNM within a specified period of time. The time period is intended to be related to the time required to convert different forms of nuclear material to the metallic component required for a nuclear explosive. For plutonium metal one significant quantity (SQ) is 8 kg. of contained plutonium as identified in *IAEA Safeguards Glossary (1987).*

Surplus fissile material storage and processing activities at the facility shall be designed/modified to accommodate international and domestic safeguards, security protection, and transparency requirements. The International Inspection Area is used by international inspectors for inspection and verification of Surplus Material. The physical inventory verification (PIV) method is dependent on the type and form of material. The inspection area houses international agency provided equipment to conduct authorized surveillance without allowing access to classified information. These activities may also include site visits for the purpose of reviewing documentation and recorded information from installed instrumentation and CCTV cameras. Special uninterruptable power supply (UPS) and other systems may be required by international agreements. International requirements are found in IAEA Information Circulars, and in *Safeguards Criteria 1991-1995 (1990)*.

The objective of IAEA safeguards is the timely detection of the diversion of significant quantities of nuclear materials to activities which have military applications. Material accountancy is used together with containment and surveillance as complementary safeguards techniques. A system of accounting for the control of all nuclear materials will be based on a structure of material balance areas (MBA).

To satisfy IAEA verification requirements, the site must establish acceptable procedures for identifying, reviewing and evaluating differences in shipper-receiver measurements, for taking acceptable physical inventories and for the evaluation of accumulations of unmeasured inventory and unmeasured losses. Additionally, an acceptable system of records showing, for each MBA, receipts for changes involving transfers into and out of such areas. Provisions must also be made to ensure that accounting procedures and other arrangements are being operated correctly. All of these features should be accommodated by the general Materials Balance and Accounting activities described in the previous section.

1.4.7 Site Characterization

Siting Philosophy

The borehole system relies mainly on natural systems to prevent mobilization and migration of emplaced fissile materials. The major element is careful site selection to ensure favorable geologic conditions that provide natural long-lived migration barriers. These conditions include deep, extremely stable rock formations, strongly reducing groundwaters (brines) with increasing salinity with depth, and most importantly, demonstrated isolation or non-communication with the biosphere over geologic timescales. The isolation is the most important characteristic, with the other conditions mainly being those that will enhance the potential of locating and maintaining the isolated zones.

Site characterization involves measurement of the surface and subsurface properties of a candidate site and the assessment of the suitability of that site for the development of a deep borehole disposal facility. This includes characterization of the vertical and horizontal flow rates of brine; geochemical composition, pH and Eh of brines at depth; temperature and salinity gradients; compositional, chemical, hydrological, thermal and mechanical properties of host rock at depth; characterization of fracture distribution and properties; borehole logging, surface seismic and cross-borehole acoustic/electrical tomographic imaging methods for definition of geologic structure and rock properties; cross-borehole pressure and tracer tests for hydrologic characterization; tectonic and seismic stability of the geologic formation.

Candidate Geologic Media with Desirable Characteristics

The different types of geological media considered for either a mined disposal or deep borehole disposal facility include: 1. Plutonic/metamorphic (“basement”) rocks, 2. Evaporites (rock salt and anhydrite), 3. Sedimentary rocks (shale and related rocks), 4. Mafic lavas (flood basalt), 5. Tuffs (consolidated volcanic ash deposits), and 6. Unconsolidated rocks or sediments.

The site selection process should consider whether geologic evidence demonstrates long term stability and conditions suitable for fissile material isolation. The following are some of the characteristics that should be taken into account when evaluating a site: 1. Minor historical seismic activity, 2. Gradual, rather than steep thermal gradient, 3. Little or no evidence of Cenozoic or Mesozoic hydrothermal, volcanic, or tectonic activity, 4. The presence of high salinity in brines at depth that exhibit geochemical evidence of long term stability (e.g., gravity stabilized density gradients, and isotopic and chemical evidence of equilibrium with the host rock). In addition, the host rock should possess 5. high mechanical strength (for borehole stability), 6. sparse, widely spaced, fractures, and 7. mineralogies and chemical characteristics that would favor fissile material isolation (e.g., high sorptive capacity for Pu and its daughter products, low abundance of natural colloids, and some buffering capacity to assure favorable water compositions).

In addition to these subsurface criteria, the site selection process should take the following surface characteristics into consideration: 1. A site should be selected sufficiently far from international borders, large population centers, 2. Reasonably close access to both rail and truck transportation, power facilities, and fresh water necessary for the construction and operation of the surface emplacement facility, and 3. Sufficiently far from any streams, lakes, and rivers were the effluents from the site processing and emplacement facilities may unfavorably affect.

Upon consideration of the available types of geologic formation for siting a deep borehole facility, it appears that a plutonic/metamorphic crystalline basement rock formation would be the best for this application.

In summary, an ideal site for a Deep Borehole Disposal Facility would have the following characteristics: (1) crystalline rock at the surface or near the surface that is continuous down to emplacement depths, (2) location in a tectonically stable region, (3) distant from population centers, and (4) distant (greater than, say, 200 km) from international borders.

Generic Site Description

The siting effort will be focused on a search for an ideal site with the following geological properties. Many such potentially suitable sites exist and should be easy to locate and characterize.

The area should be in the continental United States. It should be very flat, yet above flood plains, rural in setting and distant from major cities and air corridors. The host rock should be Precambrian crystalline rocks of the craton that are either exposed or overlain by < 1 km of Phanerozoic sedimentary rocks. The area should be extremely stable tectonically; with few recorded earthquakes with a Mercalli intensity of over V. The stress at the site should be compressional and the Thermal gradients within the ‘basement’ rocks should be low; ranging from 15 ^{o}C/ km to as high as 30 ^{o}C/km of depth. Bottomhole temperature is preddicted to range from < 60 ^{o}C to 100 ^{o}C. Heat flow patterns should indicate little or no movement of the deep fluids at the emplacement depths. The rock types should consist of crystalline high grade metamorphic or igneous rocks that exhibit very little evidence of Cenozoic or Mesozoic alteration related to hydrothermal, tectonic or volcanic processes. Pore waters at depth should possess isotopic and geochemical characteristics that suggest that the water has remained undisturbed in equilibrium with the host rock for a geologically long period. To minimize heterogeneities within the target rocks, the host rock should preferably be a plutonic body with a map area of > 100 km^2 that is relatively homogeneous texturally and structurally.

Below 1 km, the site should have a seismic velocity structure that is consistent with the absence of through-going, high permeability fractured regions. A few shallow fracture zones, with low seismic velocities, may be present, but should persist only over short distances. Permeabilities may be as low as 10^{-20} m^2. As demonstrated in other deep drillholes, the salinities of fluids will generally increase with depth, although the actual observed gradients and compositions are expected to vary from site to site, depending on the natural heterogeneity of the host rock and its history of evolution The site should be selected to maximize the reducing character of brine because the solubility of Pu, in both oxide and ceramic forms, is extremely low in reducing environments. The presence of gravity stabilized density gradients would suppress upward migration of fissile materials due to the buoyancy forces that arise from either the geothermal gradient or the small amount of heat generated by the radioactive decay of the emplaced fissile materials.

Siting Methodology

The siting process is therefore a key element in selecting a site with adequate long-term performance. The process consists of two phases. First, large geologically suitable areas are screened and a few sites selected that will be further characterized. Since it is difficult to prove a site acceptable without detailed work, unsuitable areas will be screened out through use of existing regional studies. Suitable remaining sites will be studied in more detail, using non-invasive techniques such as surface mapping, surface sample analysis, and geophysical surveys. The first phase is therefore an effort to locate areas likely to have favorable characteristics without disqualifiers.

When an absence of disqualifiers for a site is determined, the second site-specific investigation phase is begun. It is expected that several candidate sites will be chosen. At each, small diameter pilot coreholes will be drilled. The core from these holes will be subjected to extensive laboratory testing. The holes will be geophysically logged and results tied into the surface geophysical surveys. Fluid analysis and hydrologic testing on the holes will determine if favorable isolation conditions are present. Drilling parameters will be measured and used to fine tune the drilling program for the emplacement holes if the site is chosen. Additional site data will be obtained as each large diameter emplacement hole is cored and drilled. Cross-hole hydrologic and geophysical testing will be performed on each additional hole, as well as the standard logging as performed on the pilot holes.

These site-specific tests in this second phase are designed to determine if the rock mass has been functionally isolated for geologic timespans, and if the isolation can be maintained for long timescales.

1.4.8 Performance Assessment

Performance assessment studies attempt to predict the post-closure performance of the deep borehole facility in support of 1. the initial site screening and site selection phases, 2. the site characterization, facility design and licensing phases in the development of a deep borehole disposal facility after a suitable site has been selected, and 3. confimatory assessments during the construction and operation of the facility as additional data becomes available.

Performance assessment involves the quantification and prediction of the mechanisms for initiation of fluid flow; transport of plutonium and daughter products in borehole, host rock and along pathways towards the biosphere; Pu release rate from the disposal form; Pu re-concentration mechanisms and evaluation of long-term criticality risk; borehole integrity; grout durability and performance; ES&H, criticality and proliferation risk assessments; natural analog studies of naturally occurring radioactive ore bodies and fossil geologic reactors to support long-term performance predictions; integrated systems level performance; cost analyses for design optimization.

To be able to successfully undertake performance assessment leading to a successful license application, it is necessary to undertake this activity within the context of an integrated research and development, site characterization, facility design program including the following program elements:

1. *Acquiring the required field data* on the conditions at large subsurface depths through an experimental site characterization program at a generic site,

2. *Extending and specializing existing performance analysis models or developing new models* for coupled fluid flow, reactive fissile material transport, fissile material release and disposal form dissolution, downhole short and long term criticality assessments, geomechanical analyses, ES&H and proliferation risk assessments, and cost analysis to the deep borehole application,

3. *Acquiring unavailable data* required by the above predictive models through laboratory and field experiments that simulate downhole conditions (natural analog studies can provide data some of this data and assist in validation transport codes),

4. *Developing the required engineering and operations technologies* required to safely and efficiently implement the site characterization, drilling, emplacing, borehole sealing, and remote monitoring activities associated with construction, operation and post-closure performance of a Deep Borehole Disposal Facility,

5. *Performing the long term performance, risk and cost assessments* required to support the facility design and licensing activities,

6. *Demonstrating the developed drilling, emplacement and sealing technologies* through a pilot large diameter deep borehole field demonstration, and

7. *Preparing a Conceptual Engineering Design of the Deep Borehole Disposal Facility* to provide an early basis for evaluating the technical and economic feasibility and licensability of this disposition alternative.

1.5 INTERSITE TRANSPORTATION

Overview

The transportation and packaging analysis provides information on transporting the surplus fissile material and other radioactive material from the Feed Source Facilities to the Disassembly & Conversion and Deep Borehole Disposition Facilities. The analysis defines the mode of transport and package requirements for each transportation segment and defines any transportation or packaging regulatory requirements pertaining to the alternative. The package is selected to meet shielding, containment, and regulatory requirements while optimizing the cost and complexity of transporting the material, storing, handling and processing at the facilities.

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Regulations

Transportation of plutonium and associated wastes will be subject to government regulations such as the Nuclear Regulatory Commission (NRC), the Department of Transportation (DOT), and the Department of Energy (DOE). Different regulations may apply for different portions of the direct end-to-end flow depending upon which agency has authoritative control. An assumption for FMDP is that any new facility that is required to accomplish the Direct Disposal Alternative will be licensed by the Nuclear Regulatory Commission (NRC). Any currently existing site will maintain the current status of authoritative agency (DOE).

The NRC regulation (10CFR71) establishes the requirements for packaging, preparation for shipment, and transportation of licensed material. This regulation also defines the procedures and standards for obtaining NRC approval of packages and shipping procedures for fissile material and Type B quantities of other licensed materials. (A quantity of weapons-grade plutonium in excess of ~25 mg constitutes a Type B quantity per 10CFR71.) The 10CFR71 regulation incorporates, by reference, DOT regulation 49CFR170-189. Whenever possible, the DOE transports radioactive materials under NRC regulations. However, for the purpose of national security, 49CFR173.7(b) allows the DOE to ship radioactive material under escort by personnel designated by the DOE, thus waiving the DOT regulations in 49CFR170-189. This exemption, however, is rarely used and it’s use is not anticipated in the FMDP.

There are different requirements for the transportation of nuclear materials whether the movement of materials is considered onsite (intrasite) versus offsite (intersite). Currently, there are no federal regulations governing onsite transport of hazardous materials. For DOE facilities, on-site and offsite transport are defined in *DOE Order 460.1* (approved 9-22-95). Onsite is any area within the boundaries of a DOE site or facility that is fenced or otherwise access-controlled and offsite is any area within or outside of a DOE site to which the public has free uncontrolled access.

Transportation System

There are two intersite transportation segments for the end-to-end Direct Deep Borehole Disposition Alternative: 1. Between the Feed Source Facilities and the Disassembly & Conversion Facility, and 2. Between the Disassembly & Conversion Facility and the Deep Borehole Facility. These intersite transportation segments are summarized in Figure 1.1-1.

1.5.1 Transportation Between the Feed Originating Sites and the Disassembly & Conversion Facility

In this transportation segment, fissile material located at various DOE facilities is transported to the Disassembly & Conversion Facility onsite temporary storage. The categories of material requiring transportion include: pits, clean metal, impure metal, impure oxide, clean oxide, alloys, compounds, rich scrap, miscellaneous material, and reactor fuel.

Package Description

The pits under the FMDP program will be stored and transported in the Model FL or AT-400A containers. These containers can be utilized for different types of pits by using different internal fittings.

The other non-pit plutonium materials are assumed to be in on-site storage at the various DOE facilities with the material/packaging meeting *The Criteria for Safe storage of Plutonium Metals and Oxides* as specified in the DOE standard DOE-STD-3013-94 of December, 1994. For out-of-line storage, this document states that all plutonium metal and oxides (excluding pits) over 50 weight-percent plutonium shall be either:

- Sealed in a material container nested in a boundary container (until a primary containment vessel can be used); or

- Sealed in a boundary container nested in a primary containment vessel (PCV).

The design goal for the boundary container and PCV storage package is that the entire package should be maintenance free and be qualified for shipping off-site without additional repackaging.

For transporting the plutonium material (non-pit), the PCV would provide the first containment boundary. The PCV would then be loaded into another " 6M/2R-like" shipping container, which could provide double containment if required. Information regarding "6M/2R-like" packages is provided in the document *Mini-Pac Fissile Material Packaging Needs Assessment (1994)*. Two packages that exemplify the 6M/2R-like packaging are the SAFKEG and the Model 9968. These specific packages would require modifications to insure that the packaging criteria stated in DOE-STD 3013-94 are met. Further modifications would be required to insure that: 1) the packaging configuration incorporates the PCV, 2) analysis/testing is performed to show the abnormal and normal accident scenarios, and 3) the Safety Analysis Report is modified to show the changes. Many different 6M/2R-like packages can be used because the maximum dimensions for the PCV is the limiting vessel dimensions for fitting inside the secondary containment vessel of existing shipping packages. Currently, the maximum PCV dimensions are 15.24 cm (6 in.) for the outer diameter and 43.18 cm (17 in.) for the height of the container.

Shipment Information

A ten year FMDP shipment campaign has been assumed with a total quantity of 50 t of Pu. There are two intersite transportation segments as shown in Figure 1.1-1. The requirements of these segments are described below. The total number of packages and shipments is shown in Table 1.5.1-1. The information in Table 1.5.1-1 applies to all the FMDP alternatives because the program has mandated that all alternatives must accept all the front-end material for the PEIS and ROD analysis. The amount of detail that is provided in Table 1.5.1-1 has been limited due to classification issues.

Table 1.5.1-1: Intersite Transportation between Feed Source Facilities and Disassembly & Conversion Facility

Item	Value
Maximum Pu in containment vessel CV (kg)	4.5
Quantity Pu/yr (kg)	5,000
Total Disposal Quantity Pu (kg)	50,000
# packages/yr (6M/2R-like + pit containers)	3,100
Total # packages (6M/2R-like + pit containers)	31,000
SST shipments/yr	110
Total shipments	1,100

1.5.2 Transportation Between the Disassembly & Conversion Facility and the Deep Borehole Disposal Facility

During this transportation segment, Pu metal or oxide is transported in 6M/2R-like packages from the Disassembly & Conversion Facility to the Deep Borehole Disposal Facility by SST. The Deep Borehole Disposal Facility is assumed to be centrally located in the US at a generic location in the northern part of the mid-west. Each 6M/2R-like package will have two product cans containing 2.25 kg of Pu each for a total weight of 4.5 kg per 6M/2R-like package.

Shipment Information

Table 1.5.2-1 gives the packaging requirements and mode of transport for the disposal form.

Table 1.5.2-1: Intersite Transportation Between the Disassembly & Conversion Facility and the Deep Borehole Disposal Facility

Item	Value
Transported Materials	
Type	^{239}Pu metal or oxide
Physical Form	Buttons or powder
Composition	Pu or PuO_2
Isotopic Content	93% ^{239}Pu, 6% ^{240}Pu, 1% (trace isotopes)
Packaging	
Type	DOT 6M/2R-like
Certifying agency	DOE or NRC
Material weight (kg)/package	131.9
# Packages/SST	35
Weight Pu/package (kg)	4.5
Average Shipping Volumes	
Quantity Plutonium/year (kg)	5,000
Packages/year	1,111
Packages for life of project	11,110
Shipments/year	32
Total shipments	318
Routing	
Mode of transport	SST
Origin	Disassembly & Conversion Facility
Destination	Deep Borehole Facility
Costs	
Cost /package ($)	2,000
Cost of Design + Certification ($M)	N/A

2.0 CRITERIA ASSESSMENT

Overview of Criteria Assessment

The selection of a particular alternative for disposition will be based on a set of eight criteria similar to those developed for the initial screening of fissile material disposition options. These criteria, against which the Deep Borehole alternative will be assessed, are:

1. Resistance to theft and diversion by unauthorized parties
2. Resistance to retrieval, extraction and reuse by the host nation
3. Technical viability
4. Environmental, safety and health
5. Cost effectiveness
6. Timeliness
7. Fosters progress and cooperation with Russia and other nations
8. Public and institutional acceptance

These criteria can be divided into four major groups of closely related criteria. These four groups, or objectives are:

- ***Non-Proliferation***, which includes resistance to theft, resistance to reuse, and international cooperation (Criteria 1, 2 and 7),
- ***Operational Effectiveness***, which includes technical viability, cost effectiveness, timeliness and additional benefits (Criteria 3, 5, and 6),
- ***Environmental, Safety and Health***, which includes human health and safety, environmental protection, and socio-economic effects (Criterion 4),
- ***Public and Institutional Acceptance*** (Criterion 8).

Both Deep Borehole Disposition Alternatives address each of the eight criteria favorably, with the possible exception of timeliness that depends on legislative and regulatory actions. For clarity, we address the criteria in the order set by the above four objectives, noting any discriminating differences between the different Deep Borehole and other alternatives. The Immobilized Deep Borehole Disposition Alternative includes many of the pre-processing steps required by many (most) other alternatives. This will roughly equate proliferation risks inherent in the processing and transport operations, the operational effectiveness, ES&H, and public and institutional acceptance with other immobilization alternatives. Concerns over plutonium criticality, migration or release for the emplaced plutonium will be addressed in the research, development, demonstration and test phases of the program.

Non-Proliferation

The Deep Borehole Disposition Alternatives are likely to be the most proliferation resistant alternatives for plutonium disposition. The combination of great technical difficulty in retrieving the disposed plutonium and the ease of detection (by both remote and local detection technologies) make this a very secure alternative. This applies equally to diversion by the host nation and unauthorized removal. The large amount of equipment, and time it would take to retrieve the material once in place, makes detection by satellite or other remote means highly probable. These features, difficulty in retrieval and ease of detection, will set an excellent international example due to the inherent security and detectability of the disposition. The processing used for immobilization in this alternative slightly increases the proliferation risk compared to the direct borehole disposition alternatives during the operational phase although this is expected to be less important than the above considerations. However, the immobilized disposal form significantly reduces the post-emplacement proliferation risk because of the dilute concentration of plutonium dispersed in a large volume of disposal form and the consequent difficulty of retrieving and reprocessing it into weapons useable material.

Operational Effectiveness

The overall operational effectiveness of all the Deep Borehole Disposition Alternatives is very high. The technology for drilling holes to the required depth is well in hand. Existing drilling capabilities within the DOE complex are available for initial tests, and are probably adequate for the actual disposition boreholes themselves. The pre-processing required will employ well understood technologies. The relatively low cost of this borehole disposition alternative compared to other (non-borehole) options at least partially offsets the potentially longer timeline to begin disposition. This uncertainty comes largely from the regulatory and licensing requirements, requirements that are somewhat uncertain since both plutonium disposition and deep borehole disposition are relatively new concepts to the regulatory agencies. Recent efforts to compress the schedule for completion have succeeded in reducing the anticipated time-to-complete by a factor of two. Also, borehole disposition is typically feed rate limited and large amounts of fissile materials can be rapidly disposed of in a few boreholes once the facility has started operations. Thus, in summary, the operational effectiveness of this alternative is very high.

Environmental, Safety and Health

The impact of borehole disposition on both human health and safety and on the environment are expected to be quite small. The relatively compact borehole drilling facility with its modest resource requirements of this alternative minimize the project's impact on human health and the environment. ES&H concerns for the immobilization facility will be similar to those for other immobilization alternatives. As stated above, the long term migration of plutonium in the borehole environment will be assessed in the development phases. Initial assessments appear to minimize the threat of unacceptable migration or release.

Public and Institutional Acceptance

The principal public and institutional acceptance issues for this alternative (and the other deep borehole alternatives) are regulatory and licensing related. As with any of the disposition alternatives, local or regional opposition to the project will likely manifest itself in the regulatory and licensing process as well as other channels. The relative newness of the deep borehole concept may be a source of public and institutional concern and resistance. This will be partially, if not entirely, offset by the technical soundness and low risks of deep borehole disposition.

Summary

It is anticipated that this alternative will rank higher than the other borehole alternatives due to its superior long-term performance with respect to ES&H and post-emplacement proliferation resistance although it incurs more plutonium handling, processing and, possibly, greater cost to achieve this superior performance.

2.1 RESISTANCE TO THEFT AND DIVERSION

The safeguards and security systems established to preclude theft and diversion of the fissile materials in the Deep Borehole Disposition Alternative are listed in the preceding physical security and MC&A sections on facility descriptions. In this section, the safeguards and security requirements are briefly discussed and an assessment of the risk of theft and diversion posed by this Direct Deep Borehole Disposition Alternative is presented.

2.1.1 Deep Borehole Disposition Alternative S&S System Description

In this alternative the disposition process begins with the transportation and delivery of plutonium feed materials (pits, metal, oxide, residues, etc.) to the Disassembly & Conversion Facility site packaged in DOT 6M/2R-like shipping containers. The shipping container provides double containment of the contents and holds a primary containment vessel (PCV) each of which contains two Pu product cans containing approximately 2.25 kg of Pu. The shipping containers will be unpackaged in the Pu Processing Facility at the Disassembly & Conversion Facility where accountability measurements will be conducted. The Pu feed material is then processed by size reducing and/or converting feed materials to either Pu metal or oxide and packing the product in DOT 6M/2R cans of the type described above for transportation to the Deep Borehole Disposal Facility. At the Deep Borehole Disposal Facility, the transportation containers are first received and stored in a protected lag-storage area. Then, as needed, they are processed by filling the voids in the 6M/2R-like containers between the product cans and the outer container. Next they are placed within emplacement canisters (38.1 cm (15 in.) ID x 6.1 m (20 ft.) long) and encapsulated in a sealant. The emplacement canisters are then emplaced within the borehole in 152 m (500 ft.) long canister strings made by screwing the canisters together. After lowering into the borehole the space between the canister string and the borehole wall is filled with grout.

The modified conditional risk rating associated with the materials at the facility are expected to be acceptable. The primary difference between this facility, and similar processing facilities is expected to be the volume of throughput (i.e., 5 t/year of plutonium).

The ‘stored weapon standard’ will be maintained throughout the entire process consistent with DOE requirements. The ‘spent fuel standard’ is achieved and maintained following the emplacement of the canisters in the borehole. The borehole may require some post-closure monitoring and it may be possible to satisfy this by satellites in earth-orbit. Post-closure monitoring will contribute to the proliferation resistance of this disposition alternative.

Domestic Safeguards

The FMDP has established two major S&S criteria for Phase II review of disposition alternatives. These criteria reflect the domestic (Criterion 1) and international (Criterion 2) perspectives, and are based on two important factors: the 'threat' posed and the 'regime' in which the threat exists.

The primary purpose of FMDP Domestic Safeguards and Security (Criterion 1) is to protect and provide assurance of non-proliferation of the fissile material and classified information, and to instill public and international confidence in those actions. Domestic safeguards and security (S&S) is composed of two subsystems: 1. nuclear materials control and accounting, and 2. the physical protection of fissile material (FM) and nuclear weapons components against threats of diversion, theft, or radiological/toxicological sabotage. Domestic safeguards primarily address unauthorized actions perpetrated by individuals and/or sub-national groups (insiders or outsiders). The detection and prevention of an unauthorized access or removal attempt (e.g., theft or diversion) depends on the levels of safeguards and physical protection provided at the facility. Generally, safeguards are more easily applied and more readily verified when materials are in the form of discrete, uniquely identifiable items, as opposed to difficult to measure bulk forms, common in chemical processing activities. The DOE, and the NRC, have established requirements for domestic safeguards and security. In the U.S., both the DOE and the NRC have specific orders or regulations that identify physical protection, and material control and accounting requirements. These specify safeguarding measures that must be followed as determined and negotiated based upon the category and attractiveness of the fissile material. For this alternative it is assumed that the plutonium processing facilities will be DOE regulated with DNFSB oversight and will not be subject to NRC regulations. The remaining facilities also will be assumed to be governed by NRC regulations.

The responsibility of the domestic regime is to prevent unauthorized access to its material either by individuals or groups within its own weapons complex (such as disgruntled workers) or by national or international terrorist groups, criminal organizations, etc. The domestic threats can be grouped into four categories as: **theft** (e.g., unauthorized removal of material by an individual/group outside the host nation's weapons complex), **diversion** (e.g., unauthorized removal of material by individual/group belonging to the host nation's weapons complex), **retrieval** (unauthorized access by outside individuals/groups after final disposition), and **conversion** (the conversion of retrieved material into weapons usable form).

2.1.2 Applicable S&S Requirements and Measures

The Domestic Theft and Diversion Criterion (Criterion 1) evaluates the system protection and resistance to theft by an outsider, and/or an insider and retrieval after final disposition by outside groups. Theft or diversion of material refers to both overt and covert actions to remove material from the facility. This is perpetrated by unauthorized parties including terrorists, sub-national groups, criminals, and disgruntled employees. Protection of the material and information from these parties is a domestic responsibility, not an international one. There are a number of possible adversary groups with different motivations and capabilities. The actions could be overt such as a direct attack on a facility or could involve covert measures that might utilize stealth and deception, as well as possible help from an 'insider.' It is assumed that all facilities will meet the necessary S&S requirements. Therefore, many of the S&S standards (guards, gates, etc.) are not directly discussed in this document (see *Wijesinghe et al., January 15, 1996d*). The threats to facilities will be different depending the form of the material, the activities at the facility and the barriers to theft (both intrinsic to the material and to the facility). For each of the facilities in this alternative a brief discussion is presented below of the *potential risks of theft.*

An essential element in assuring the resistance of fissile material to theft and proliferation, is the safeguards and security applied to the material, based on its form. The form of the material reflects the intrinsic properties of the material, which dictates its attractiveness for its use in nuclear weapons. However, the form of the material alone does not provide proliferation resistance. Safeguards and security systems should be applied in a graded approach based on the form of the material and its attractiveness.

The DOE defines the attractiveness level of nuclear material through a categorization of types and compositions that reflects the relative ease of processing and handling required to convert that material to a nuclear explosive device. Table 2.1-1, derived from DOE Order 5632.33B (9/7/74) on *Control and Accountability of Materials* identifies these categories.

The level of protection accorded to an attractiveness level depends on the quantity or concentration of the material. Each category of protection has its own requirements from the highest level of protection Category I, for assembled weapons, to Category IV for self-protecting (irradiated) forms and less than three kilograms of low-grade material. Protection of the material is accomplished through a graded system of deterrence, detection, delay, and response as well as material control and accountability. Layers of protection may then be applied to protect material of greatest attractiveness within the innermost layer and with the highest controls. Material of lesser attractiveness does not require as many layers of protection and fewer controls.

The S&S requirements for this alternative are primarily driven by the attractiveness of the material as defined in DOE Order 5633.3B and/or NRC requirements (10 CFR 73 and 74). Category I and/or strategic FM must be used or processed within a DOE approved Materials Access Area (MAA). The requirement for an MAA and vault-type room storage may mean that certain physical protection enhancements will be needed beyond what currently is present at existing facilities. The physical barriers at the Protected Area boundary normally consist of two barriers with a redundant intrusion detection system. The Protected Area boundary must also provide for a barrier from unauthorized vehicle penetration. The access control points into the PA are normally made of a bullet resistant material. Duress alarms will be necessary at all manned access points. There will be enhanced entrance/exit inspections of personnel, vehicles and hand-carried items. MAA/PA portals typically have metal detectors, FM detectors, and/or X-ray machines for hand-carried items.

made of a bullet resistant material. Duress alarms will be necessary at all manned access points. There will be enhanced entrance/exit inspections of personnel, vehicles and hand-carried items. MAA/PA portals typically have metal detectors, FM detectors, and/or X-ray machines for hand-carried items.

Table 2.1-1 Nuclear Material Attractiveness and Safeguards Categories for Plutonium (DOE)

MATERIAL DESCRIPTION	Attractiveness Level	Pu/^{233}U Category (Quantities in kg)			
		I	II	III	IV[1]
WEAPONS Assembled weapons and test devices	A	All Quantities	N/A	N/A	N/A
PURE PRODUCTS Pits, major components, buttons, ingots, recastable metal, directly convertible materials	B	≥ 2	$\geq 0.4 < 2$	$\geq 0.2 < 0.4$	< 0.2
HIGH-GRADE MATERIAL Carbides, oxides, solutions ($\geq$ 25 g/l) nitrates, etc., fuel, elements and assemblies, alloys and mixtures, UF_4 or UF_6 ($\geq 50\%$ ^{235}U)	C	≥ 6	$\geq 2 < 6$	$\geq 0.4 < 2$	< 0.4
LOW-GRADE MATERIAL Solutions (1 - 25 g/l), process residues requiring extensive reprocessing, moderately irradiated material, ^{238}Pu (except waste), UF_4 or UF_6 ($\geq 20\% < 50\%$ ^{235}U)	D	N/A	≥ 16	$\geq 3 < 16$	< 3
ALL OTHER MATERIALS Highly irradiated forms, solutions (≥ 1 g/l), uranium containing < 20 % ^{235}U (any form or quantity)	E	N/A	N/A	N/A	Reportable Quantities

[1]The lower limit for category IV is equal to reportable limits in the Order

2.1.3 Identification of Diversion, Theft, or Proliferation Risks

Tables following this narrative provide information about the flow of plutonium through this alternative, along with a description of the material and its changing attractiveness levels.

- ***Disassembly & Conversion:*** The plutonium processing building of this facility will be a Category I facility. A number of different forms are received by the plutonium processing facility (Cat. I-B through II-D). This material is either size reduced or converted into oxide (Category I-C). For this facility most of the material is in a very attractive form with minimal intrinsic barriers. There are a large number of processing steps that provide increased opportunities of covert theft. Since many of the processes involve bulk material the accountability measures will involve bulk measurements. In the case of an overt theft attempt the targets of greatest concern would be the plutonium pits, pure metal, and oxides that are very transportable. However, these materials would be under significant protection so that the risk associated with an overt event would be acceptable.

- ***Deep Borehole Disposal Facility:*** The disposal material is received in DOT 6M/2R-like double-contained transportation packages within shipping casks. The material is processed by filling the voids in the PCVs with sealants, and encapsulating the PCVs in emplacement canisters. The emplacement canisters are then screwed together to form long canister strings which are then lowered into and sealed in the boreholes.

Risk Assessment

The measures identified for this criteria are the *environment (S&S), material form, and S&S assurance*. These measures are briefly described below and a qualitative discussion of the relative risks is presented for each of the facilities in this alternative. The Tables provided below contain specific information derived from Alternative Team data and other sources (DOE Orders, etc.). S&S Table 4 summarizes the potential risks. ***This assessment is highly qualitative, and is based only on available data.*** This assessment must be refined in Phase III of the decision process (prior to ROD). It must also be supported by the FMDP multiple attribute decision analysis effort.

Environmental Conditions

The logistics, physical location, and the state during processing, transportation, or storage affect the opportunities for theft. The more complex the logistics (e.g., transfers and process locations), the more opportunities there are for theft. The more inaccessible the physical location (e.g., storage locations), the fewer opportunities are there for theft. The environmental conditions of the Deep Borehole Disposal Alternative is discussed below and their S&S attributes are listed in Table 2.1-2.

- ***Disassembly & Conversion Facility:*** This facility involves a large number of processing steps with a relatively high throughput. Based on the quantity and attractiveness of the material, this will be a Category I facility. Waste streams containing fissile material will be generated and thus require monitoring to prevent possible theft or use as a diversion path. There will be lag storage in an active vault. There will be no intrasite transport movements (i.e., outside of the facility). SSTs will be used to deliver and pick up the material. Although operations for a single batch are relatively short there will a large number of batches needed to meet the proposed throughput obligations, and therefore the opportunities for possible adversary actions are numerous. Waste streams containing fissile material will be generated during processing activities.. No fissile material waste streams are generated in storage.

- ***Deep Borehole Disposal Facility:*** The S&S environment issues of the materials remain the same as for the output materials from the Disassembly & Conversion Facility.

Table 2.1-2: Environment Assessment for Direct Deep Borehole Disposition

Environment	Intersite Transport	Disassembly Conversion nn	Intersite Transport	Borehole Facility	Borehole Disposal
Activity	Pu feed to Front End Facility	Receiving, NDA, and processing	Pu metal & oxide to Borehole Facility	Receiving, NDA, repacking in canisters	Emplaced downhole
Duration		3 mths		3 mths.	Forever
Throughput	5 t/yr	5 t/yr	5 t/yr	5 t/yr	5 t/yr
Waste Streams	No	Yes	No	No	No
Lag Storage	N/A	Yes	N/A	Yes	N/A
Maximum Inventory	N/A	2 t	N/A	1.67 t	50 t in 4 holes
Intrasite Transport	N/A	No	N/A	Yes, to Borehole	No
Number of Processing Steps	0	3	0	3	1

Material Form

Attractiveness based on physical, chemical, or nuclear (isotopic and radiological) makeup of the nuclear material during processing, transportation, or storage. The risk of theft for weapon use is reduced if the material is only available in small quantities, the physical and chemical form of the material or matrix that makes recovery difficult, or the material has an unattractive isotopic content. The material forms present in the Deep Borehole Disposal Alternative are discussed below and their S&S attributes are listed in Table 2.1-3.

- ***Disassembly & Conversion Facility:*** The material received at the plutonium processing facility is the most attractive material for this alternative (e.g., pits, pure metal and oxide). In the case of pit conversion the attractiveness goes from I-B to I-C. For oxides and other high-grade material the attractiveness level remains at I-C. Overall, the material has very low intrinsic barriers, and is transportable. It has a very low radiological barrier primarily due to the presence of Americium. It is in most cases in a very pure form, as a metal or oxide, and its isotopic composition makes it very usable for a nuclear device. Because pits and some other weapons usable materials are being processed, some of the material and waste streams will be classified.

- ***Deep Borehole Disposal Facility:*** The form attractiveness of the materials remain basically the same as in the Disassembly & Conversion. However, after emplacement and sealing of the borehole, the intrinsic (self) protection of the geologic barrier is very significant.

Table 2.1-3: Material Form Assessment for Direct Deep Borehole Disposition

Material Form	Intersite Transport	Disassembly Conversion	Intersite Transport	Borehole Facility	Borehole Disposal
Activity	Pu feed to Front End Facility	Receiving, NDA, and processing	Pu metal & oxide to Borehole Facility	Receiving, NDA, repacking in canisters	Emplaced downhole
SNM Input Form	Metal, oxide and other	Metal, oxide and other	Pu metal or oxide	Pu metal or oxide	Pu metal or oxide
SNM Output Form	Metal, oxide and other	Pu metal or oxide	Pu metal or oxide	Pu metal or oxide	
Concentration of Pu	> 90 %	> 90%	> 90%	> 90%	> 90%
Attractiveness Category	I-C	I-B to I-D	I-C	I-C	I-C
Item Mass/ Dimensions	14 cm (5.5in) x 50.8 cm (20 in) PCV 4.5 kg/PCV		14 cm (5.5in) x 50.8 cm (20 in) PCV 4.5 kg/PCV		38.1 cm (15 in) IDx6.1m(20 ft) long canister 40.5 kg/can.
Self Protecting	No	No	No	No	Yes - SQ difficult to retrieve from borehole

Safeguards and Security Assurance

The effectiveness of S&S protection depends on the MC&A characteristics, and physical protection capabilities (not directly discussed here) of the processes and facilities. The S&S assurances of the Deep Borehole Disposal Alternative are discussed below and their attributes are listed in Table 2.1-4.

- ***Disassembly & Conversion Facility:*** Material received into this facility (e.g., pits and containers with TIDs) would require item accountancy. Once the material has been removed from the 'container' bulk accountancy would be necessary. Many of the items are small and many operations involve hands-on activities. In addition to destructive assay other non-destructive assay (NDA) would be performed. As mentioned previously the pits and some other material will be classified. This may also apply to waste streams.

- ***Deep Borehole Disposal Facility:*** Item accountability is used for the casks. No access is available to the material itself although access to the casks is possible. All movements of the casks require special handling equipment.

Table 2.1-4: Safeguards and Security Assurance for Direct Deep Borehole Disposition

Safeguards & Security	Intersite Transport	Disassembly Conversion	Intersite Transport	Borehole Facility	Borehole Disposal
Activity	Pu feed to Front End Facility	Receiving, NDA, and processing	Pu sealed in 6M/2R-like canisters to Borehole Facility	Receiving, NDA, sealing in large emplacement canisters	Emplaced downhole
No. of Material Balance Areas	1	1-3	1	2	0
Type of Accounting	Item	Item & Bulk	Item	Item	N/A
Nuclear Measure	N/A	Calorimetry, gamma, seg. gamma neutron	N/A	Calorimetry, gamma, seg. gamma neutron	N/A
Classified Matter	Yes	In - Yes Out - No	No	No	No
Accessibility	THN	THN	CHN	CHN	CRN

Ability To Achieve The Spent Fuel Standard

The 'spent fuel standard' means that the material is comparable to existing spent fuel at commercial reactors with respect to its environment, material form and safeguards and security. *The final disposition form, environment, and S&S for this alternative meets the spent fuel standard.* Prior to borehole disposition the material does not meet the spent fuel standard and therefore protection commensurate with its attractiveness level must be provided.

S&S Transportation Related Issues

For all Category I material Safe Secure Trailers (SST) will be used to move the material between facilities (Inter-Site). A secure loading/unloading area must be available to ship/receive, verify, and store the Category I material. With respect to other transport activities (e.g., between processing and borehole), there are inherent S&S risks for overt theft scenarios and a much lower risk for covert theft attempts. Minimizing the number and/or duration of the transport steps is desirable.

Primary regulatory requirements for shipment of special nuclear material (SNM) are covered in 10 CFR 71-73, *Physical Protection of Plants and Materials*, and 49 CFR 100-177, *Transportation*. From this and other regulations, DOE issued two documents controlling the shipment of SNM: DOE Order 5632.1C, *Protection and control of Safeguards and Security Interests*, and DOE Order 5633.3B, *Control and Accountability of Nuclear Materials*. Table I-2 in DOE Order 5633.3B defines four Safeguards Categories (I through IV) and five attractiveness levels (A through E) of materials ranging from weapons to pure products to other material grades. This table is the basis for determining the DOE level of Safeguards & Security (S&S) control required for shipment of SNM.

Transportation of SNM such as plutonium exposes the materials to threats of theft and diversion when outside the controlled areas of secured nuclear facilities. The risk of theft and diversion of SNM during transportation can, and should, be minimized by reducing the number and duration of transport steps whenever possible. The risk of diversion or theft of the Pu is greatest during the intersite transportation segments when the material will be moving on public highways or railroads.

Safeguards and security are provided for the two intersite transportation segments, described in Sections 1.5.1, and 1.5.2 as required by DOE Order 5633.3B:

1. The fissile material shipped in both deep borehole alternative intersite segments, described in Sections 1.5.1, and 1.5.2, is expected to consist of Category I and II quantities that fall within attractiveness levels A and B. As a result, safeguards and security are provided for these materials through shipment by Safe Secure Trailer (SST) in the DOE/AL Transportation Safeguards System.

2. The fissile materials in the intrasite segment, i.e., between storage and processing, are also expected to consist of Category I and II quantities with attractiveness levels A and B. However, their movement will occur totally within the boundaries of the site under site security control. In this case there are inherently less S&S risks for overt theft scenarios and a much lower risk for covert theft attempts.

2.2 RESISTANCE TO RETRIEVAL AND REUSE BY THE HOST NATION

The surplus fissile materials that are associated with the process are resistant to retrieval and reuse by the host nation. The primary elements of the proliferation resistance are described in previous sections of this document. In general, these barriers to retrieval and reuse include the IAEA's independent verification attempts, the difficulty of completing the task undetected by IAEA representatives, and significant task time. Given the substantial proliferation resistance associated with this program (i.e., the difficulty of retrieving the material following emplacement), the materials involved are only considered credible targets prior to emplacement.

2.2.1 International Safeguards and Non-Proliferation

The responsibility of the international regime is to prevent the host country from diverting, retrieving, or converting material that has been declared surplus. Thus, the context of S&S should be viewed not only from the U.S. DOE perspective, but from the perspective of another country looking at the U.S. While application of both domestic and international safeguards may seem excessive, a very important purpose of U.S. DOE Fissile Materials Disposition Program is to set an example for other countries to follow.

The international threats can be condensed as: **diversion** (unauthorized removal of material by the host nation itself in violation of the international regime before final disposition has taken place), **retrieval** (unauthorized access by the host nation in violation of the international regime after final disposition), and **conversion** (the conversion of retrieved material into weapons usable form).

This area includes FMDP activities that may be affected by international and/or bilateral agreements, to include areas that may be subject to the International Atomic Energy Agency (IAEA). International Safeguards (ISG) are comprised of two subsystems, nuclear materials accountancy and materials containment and surveillance (C/S), which are required to satisfy international inspection agreements. International S&S is focused on the independent verification of material use through material accountancy programs, and containment and surveillance systems.

The IAEA has established a set of "Safeguards Criteria" for the MC&A, and the C/S of fissile material. The requirements in this area are derived from IAEA Statutes and Informational Circulars. The IAEA, in concert with member states (most notably the U.S.A) has also developed recommendations for states to develop appropriate domestic security measures, but they are recommendations, and not normally audited requirements. The IAEA safeguards criteria and security recommendations are typically based on practices followed in the U.S.A. and agreed upon by the IAEA member states. Domestically the DOE and NRC are the S&S ‘policing agencies’ (depending upon jurisdiction). However, internationally there is no direct police organization for Domestic Safeguards and Security. Specifically, the International Atomic Energy Agency has no jurisdiction or obligation to oversee the measures taken by a state (or host nation) to address unauthorized access to special nuclear material (Criterion 1). In this alternative it is assumed that all facilities and areas except the plutonium processing area will be subject to IAEA safeguards. Depending on agreements that would be made, between the U.S. and the IAEA, part of the Plutonium Processing Facility may, or may not, come under IAEA safeguards. The key issue here being the protection of classified information known as Restricted Data (nuclear weapons design information).

2.2.2 Applicable S&S Requirements and Measures

The International Diversion, Retrieval, Extraction, and Reuse (Criterion 2) criterion evaluates the system resistance to diversion of material before final disposition by the weapon state itself, retrieval of material after final disposition by the weapon state itself, and conversion of the material back into weapon usable form **covertly** by the host nation/state. Again the *material form*, *environment* and *safeguards* are particularly important. Additionally, the *irreversibility* of the material form is important for assessing its reuse in nuclear weapons. Nuclear material for this alternative falls under the IAEA categories of unirradiated direct use (e.g., Pu metal and compounds, MOX powder and pellets, MOX fuel rods and assemblies). The only existing world-wide inspection regime that exists to address this threat is the International Atomic Energy Agency (IAEA). One mission of the IAEA is timely detection of the diversion of nuclear material from declared nuclear activities. An important measure used by the IAEA is the 'significant quantity' (SQ) which is 8 kg for Pu. Since the state owns and operates the physical protection and material control and accountancy measures, the IAEA does not rely on these systems to fulfill IAEA obligations. However, IAEA does perform independent verification of the data from the state's system of material control and accountancy. The IAEA, in performing its safeguards inspection activities, audits the facility records and makes independent measurements of selected samples of each kind of nuclear material in the facility. To help them fulfill their responsibilities, this verification is coupled with a technology known as 'Containment and Surveillance' that is designed to provide 'continuity of knowledge' during an inspector's absence. Much of the C/S equipment used by the IAEA is very similar in technology, and in some cases nearly identical, to the seals and surveillance equipment used by DOE and NRC in physical protection functions. Although the technologies may be the same, the objectives are different. For example, domestic requirements are usually monitored in real-time or near real-time. However, the IAEA may use unattended monitors (CCTV recording, etc.) and return to a site only once every 3 months to check and verify activities.

The philosophies and implementation of international safeguards (commonly referred to as IAEA safeguards) are substantially different from domestic safeguards and security (as DOE and NRC practice). It is likely that these activities will require additional accountability verification (e.g., identification, weighing, sampling and analysis and non-destructive assay (NDA), increased inventories and item checks, containment and surveillance (C/S) measures installed throughout the facilities (e.g., surveillance, seals, monitors, tags), space for inspectors and equipment for independent measurements. Additionally, classified and other sensitive information may need to be protected differently from current practice, because of the presence of foreign national inspectors not cleared by the IAEA. Under current laws certain information cannot be divulged to IAEA inspectors (e.g., disclosure of weapons design information violates the Atomic Energy Act and the 1978 Nuclear Nonproliferation Policy Act). Therefore at least part of these facilities may not be under international safeguards and therefore verification by the IAEA is not possible, until agreements between the IAEA and the U.S. can be accomplished. A number of different options addressing this problem are being considered.

S&S Transportation Related Issues

The only existing world wide inspection regime that exists to address this threat is the International Atomic Energy Agency (IAEA). IAEA safeguards can be applied to SST transportation of plutonium materials. Tamper indicating seals can be applied to packages containing surplus fissile material and the cargo compartments of SST vehicles provided the application does not compromise the SST security features. Inspection of SST loading and unloading that does not require access to vehicle design features, and monitoring of SST payloads that does not compromise security are also permitted. Inventorying of payloads prior to shipment and following receipt is allowed provided the excess fissile material does not contain restricted data (RD).

2.2.3 Possible Diversion, Retrieval, and Reuse Risks

There is an inherent limitation on the accuracy of NDA measurements that presents an increased risk of diversion at high throughput facilities. This is where C/S plays an important role in assuring material accountability. For each of the facilities in this alternative a brief discussion is presented below of some of the potential risks to diversion. Existing domestic protective measures will help mitigate these risks, as a covert attempt to divert a significant quantity will require multiple accomplices and greater amounts of MC&A steps to be subverted in order to avoid detection.

As in Criterion 1, the measures of the *environment*, *material form* and *S&S assurance* contribute to this criterion. Thus, the information found in the provided Tables are applicable. However, the *capabilities of the adversary* (e.g., the host nation) must be also be considered when analyzing this information. S&S Table 2.2-1 summarizes the analysis for Criterion 2. As for Criterion 1 the following discussion is very qualitative and must be refined and expanded in the FMDP Phase III process as more comprehensive analysis can be completed, and as more information can be made available. The primary measures are the irreversibility of the material forms (e.g., the ability to convert the material into weapons usable form) and the ability to detect diversion, retrieval and conversion. The performance measures that demonstrate effectiveness in this area are:

Table 2.2-1: Potential Risks for Threats and Criteria 1 & 2 for Direct Deep Borehole Disposition

	Inter-Site Transport	**Disassembly Conversion**	**Inter-Site Transport**	**Borehole Facility**	**Borehole Disposed**
Threat					
Covert Threat	Medium	High	Medium	Medium	Low
Overt Threat	Medium	Medium	Medium	Medium	Low
Diversion	Medium	High	Medium	Medium	Low
Criterion 1					
Material Form	High	High	High	Medium	Low
Environment	Medium	Medium	Medium	Medium	Low
Safeguards and Security	Medium	High	Medium	Medium	Low
Criterion 2					
Detectability	High	High	High	Medium	Low
Irreversibility	High	High	High	Medium	Low

- ***Difficulty of Diversion, Retrieval, and Reuse:*** This is the difficulty of retrieval of surplus Plutonium and its reuse in weapons. This establishes the timeliness and irreversibility criteria and the level of safeguards required. The *Disassembly & Conversion* process involves very attractive material and high throughputs. The accessibility of the material, low intrinsic barriers and the large number of processing steps makes the risk to possible diversion a concern. Once the material has been diverted the pure metal and oxide could be reused in a nuclear device relatively easily. Because pits and other material in this facility are classified, they would not be under international safeguards unless restricted data could be protected. In *Deep Borehole Disposal*, the storage of the material in massive casks in a deep geologic borehole makes diversion very difficult, expensive, and easily detected by C/S measures. A considerable effort would be required to retrieve this material.

- ***Assurance of Detection of Retrieval:*** This is the difficulty of detection or diversion of a significant quantity of material. This depends on the following factors: 1. The ability to measure material, the accuracy of applicable NDA techniques, the presence of waste streams, and classification issues which may prohibit measurement, and whether item accountancy instead of bulk accountancy methods can be applied, 2. Containment and surveillance systems, and 3. Timeliness of detection. The *Disassembly and Conversion*, the process will involve large quantities of bulk material and very high throughputs. This makes material accountability very difficult and in some ways inadequate for the IAEA requirements. It will be necessary to have containment and surveillance, as well as other S&S measures, to ensure that material is not being diverted. The presence of classified material/information further complicates safeguards with respect to international inspection. In *Deep Borehole Disposal*, the casks will be sealed, item accountancy performed and C/S measures implemented. Because of the size and mass of these casks is quite large, the risk to diversion is lowered. The emplacement of this material in a deep geological borehole, along with continuing C/S measures, will ensure the risk after disposition remains acceptable.

2.3 TECHNICAL VIABILITY

Summary

Deep borehole disposition appears to be viable for implementation. Needed technologies are readily available with some reasonable extrapolation. The primary uncertainties revolve around legislation, regulation, siting, licensing and public acceptance, but these issues are qualitatively similar to those faced by other disposition alternatives. Legislative mandate may be required for any disposition alternative. Siting and public acceptance are potential problems with any new nuclear facility. Timely implementation of any alternative probably requires a firm social and congressional mandate and this concept is no different in that regard.

2.3.1 Maturity of Technologies

While no deep borehole facilities for plutonium disposition have ever been developed, many of the technologies needed for this alternative are quite mature, and the basic concept has been considered before.

The front end technologies for processing and converting the various potential Pu feed forms are similar to, or less demanding than those for all other disposition alternatives. Transportation, MC&A and Safeguards technologies are demonstrated, although continued improvements may be desirable. The borehole drilling technology is available as an extrapolation from large hole techniques for nuclear weapons testing and deep drilling for resource exploration and geotechnical research. Emplacement methods are similar to proven techniques for emplacing large heavy nuclear weapons tests. Stemming and sealing technology will require extrapolation from methods used for nuclear testing and resource recovery. Indeed, equipment already in DOE inventory, and existing work crews, could probably carry out each activity required.

In the course of developing pre-conceptual designs from which to assess FMDP PEIS discussions were held with experts in each of the relevant technology areas for deep borehole disposition. The feedback received was quite encouraging, and indicates that most of the technologies needed match well with current state of the art. Those areas which require custom development, demonstration, or extrapolation from existing capabilities have been included in the Deep Borehole Disposal Facility R&D Plan, with activities and schedules for completion.

The overall concept of deep borehole disposition has been considered in recent decades for disposal of both hazardous and radioactive wastes. This concept received significant investigation in the 1970s for disposal of high-level radioactive waste (HLW) and spent nuclear reactor fuel (SNF). Similar studies have been conducted in other countries including: Russia, Sweden and Belgium. Russia has experience in well injection of radioactive wastes, although these wells would not be considered "deep" in the context of this alternative.

Quantitative Assessment of Technical Maturity

The technical maturity of the Immobilized and Direct Deep Borehole Disposition Alternatives were quantitatively evaluated by first decomposing the unit processing operations of each alternative according to the second-level processing flow diagrams and assigning an unweighted technical maturity level to each unit operation according to the 12-level maturity scale given in Table 2.3.1-1. This 12-level maturity scale was graded from the conceptual stage (level 1), laboratory feasibility testing (levels 2-4), prototype testing (5-10) to commercialization (levels 11-12).

Table 2.3.1-1: Technical Maturity Scale for Disposition Alternatives

Value	Designation	Description
1	Conceptual	Basic principles of concept, function, and potential application have been proposed.
2	Lab-1	Some scientific investigations (calculations and/or experiments conducted)
3	Lab-2	Scientific investigations (calculations and/or experiments) currently underway.
4	Lab-3	Scientific feasibility demonstrated.
5	Prototype-1	A basic engineering system has been defined to implement technology principles, and to determine if the system can perform the function in the specific application of interest.
6	Prototype-2	Functions critical to the performance of the engineering system have been identified and verified with applicable computer codes and general experimental data.
7	Prototype-3	Design trade-offs for the engineering system have been identified to establish a reference design configuration. Initial collection of safety-related data is being performed. Existing technologies are available but have not been applied to this application..
8	Prototype-4	The system design is complete. The technology development process begins transition into a technology demonstration. Initiated data gathering to support licensing.
9	Prototype-5	The technology development process has progressed to integrated system demonstration. Collection of safety-related data is complete.
10	Prototype-6	A final design is approved or approval is pending with no outstanding issues of significance. An integrated system has been demonstrated at a scale relevant to the final application in the proper operating environment.
11	Commercial-1	A facility or process is operational or has been operational at the desired scale or throughput.
12	Commercial-2	A facility or process is operational and is available.

Relative importance weights, graded on 3-level scale (0.1, 1, 10), were then applied to weight the technical maturity of each unit operation according to its importance to the viability of the alternative as a whole. The two weighted technical maturity measures for each Facility and the Alternative as a whole were computed on a 0-12 scale and a 0-1 scale according to the definitions given below from the weighted technical maturities of the operating units for each surface facility and the post-closure ES&H performance for the Direct Deep Borehole Disposition Alternative.

Table 2.3.1-2: Weighted Technical Maturities of Subsystems/Processes in the Direct Deep Borehole Disposition Alternative

	DIRECT DISPOSITION SUBSYSTEM/PROCESS	Technical Maturity	Relative Importance Weight	Weighted Technical Maturity
	Disassembly & Conversion Facility			
1	Truck & CRT Loading/Unloading	11	0.1	1.1
2	Shipping/Receiving	11	0.1	1.1
3	Gas Sampling	11	1	11
4	Special Recovery	11	1	11
5	Pit Disassembly	7	1	7
6	Hydride/Dehydride	7	1	7
7	Oralloy Decontamination	11	1	11
8	Concentration	11	0.1	1.1
9	Denitration	7	0.1	0.7
10	Passivation Furnace	11	0.1	1.1
11	Size Reduction	11	1	11
12	Halide Wash	9	1	9
13	Precipitation & Filtration	11	1	11
14	Pyrolysis & Calcination	6	1	6
15	Off-Gas Treatment	9	1	9
16	Packaging/Void Fillling	10	10	100
17	Interim D&C Facility Storage	11	1	11
18	Transport to Borehole Facility	11	1	11
		b	c	d
A	**Total Contribution to Score**		**23**	**220**
B	**Maximum Possible Score**		**180**	**270**
C	***TECHNICAL MATURITY (0-1) Ad/Bd***			***0.82***
D	***TECHNICAL MATURITY (0-12) Ad/Ac***			***9.8***

Table 2.3.1-2: Weighted Technical Maturities of Subsystems/Processes in the Direct Deep Borehole Disposition Alternative (Continued)

	DIRECT DISPOSITION SUBSYSTEM/PROCESS	Technical Maturity	Relative Importance Weight	Weighted Technical Maturity
	Deep Borehole Disposal Facility			
1	Security Inspection	11	1	11
2	Shipping Package Unloading	11	1	11
3	Shipping Package Removal	11	1	11
4	SNM Accountability Confirmatory Measurements	11	10	110
5	Temporary Container Storage	11	1	11
6	Placing Primary Container in Empl. Canister	11	1	11
7	Emplacement Canister Filling/Sealing	10	10	100
8	Emplacement Canister Seal Closure	10	1	10
9	Emplacement Canister Inspection	11	1	11
10	Emplacement Canister Temporary Storage	11	1	11
11	Emplacement Canister Loading on Transporter	11	1	11
12	Emplacement Canister Transport to Borehole	11	1	11
13	Empl. Canister Unpacking/Final Inspection	11	1	11
14	Emplacement Canister String Assembly	7	1	7
15	Emplacement Canister String Positioning	7	1	7
16	Emplacement Canister String Lowering	7	10	70
17	Cement Grout Mixing	12	1	12
18	Emplacement Monitoring	7	1	7
19	Sealing Emplacement Canister in Borehole	7	10	70
20	Installing Undercut Seals	7	1	7
21	Installing Containment Zone Borehole Seal	7	10	70
22	Post-Closure Monitoring (Security & ES&H)	11	10	110
		b	c	d
A	**Total Contribution to Score**		**76**	**690**
B	**Maximum Possible Score**		**220**	**912**
C	***TECHNICAL MATURITY (0-1) Ad/Bd***			***0.76***
D	***TECHNICAL MATURITY (0-12) Ad/Ac***			***9.1***
	Post-Closure ES&H Performance			
	Post-Closure Performance Weight Ratio %		25	
	Total contribution to score		99	910
	Post-Closure ES&H	6	32.83	*197.0*
	DEEP BOREHOLE ALTERNATIVE	b	c	d
A	**Total Contribution to Score**		**131**	**1,107**
B	**Maximum Possible Score**		**400**	**1,576**
C	***TECHNICAL MATURITY (0-1) Ad/Bd***			***0.70***
D	***TECHNICAL MATURITY (0-12) Ad/Ac***			***8.4***

Technical Maturity of Alternative on 0-12 scale:

$$TM^{0\text{-}12} = [\ \Sigma\,(RIW_i \times TM_i)\ ]\ /\ [\ \Sigma\,(RIW_i)\ ] = Ad/Ac$$

Technical Maturity of Alternative on 0-1 scale:

$$TM^{0\text{-}1} = [\ \Sigma\,(RIW_i \times TM_i)\ ]\ /\ [(TM)_{MAX}\ \Sigma\,(RIW_i)\ ] = Ad/Bd$$

where, TM_i is the technical maturity and RIW_i is the relative importance weight of the i-th process. TM_{MAX} is the maximum technical maturity score of a process (i.e., 12). The summation is carried out over all of the unit processes. *A,B,d* and *c* refer to the rows and columns in Tables 2.3.1-2 and 2.3.1-3 where there values are computed.

The impact of post-closure ES&H performance (i.e., isolation of the disposed plutonium from the biosphere and criticality safety) on the technical viability of the two disposition alternatives was taken into account separately from the process of disposing of the plutonium by treating it as a yet another unit process. The relative importance weight assigned to post-closure performance was selected to yield a specified percentage contribution to the total score. By agreement across disposition alternatives, the pre-closure disposition operations and the post-closure performance are assigned relative importance weights of 0.75 and 0.25, respectively.

The technical maturity measures computed for each of the two deep borehole disposition alternatives are given in Table 2.3.1-3. From this Table it can be seen that the overall technical viabilities of the Immobilized and Direct Disposition Alternatives are very nearly the same. It can also be seen that while the pre-closure operations of the simpler Direct Disposition Alternative are more technically mature, the Immobilized Disposition Alternative is more technically viable than Direct Disposition with respect to post-closure ES&H performance. In this context, in deep borehole disposition the spent fuel standard is achieved upon emplacement of the disposal form within the borehole rather than during the processing operations at the surface. Therefore, we believe that in the assessment of technical viability the weighting of the pre-closure:post-closure weighting of 75%:25% should be changed to 25%:75% in favour of post-closure performance. The results for 75% weighting of post-closure performance given in Table 2.3.1-3 show that the impact of weighting post-closure performance more heavily is to decrease the technical viability of the direct disposition alternative relative to the immobilized disposition alternative. This reflects more appropriately the increase in performance gained as a result of immobilizing the plutonium at extra cost.

Table 2.3.1-3: Weighted Technical Maturity Summary for Deep Borehole Disposition Alternatives

Facilities & Alternatives	Technical Maturity (0-1 Scale)	Technical Maturity (0-12 Scale)
IMMOBILIZED DISPOSITION		
Disassembly & Conversion Sub-Facility	0.78	9.4
Immobilization Sub-Facility	0.68	8.2
Diasssembly, Conv. & Immobilization Facility	**0.71**	**8.5**
Deep Borehole Disposal Facility	**0.69**	**8.3**
Post-Closure ES&H Performance	**0.67**	**8.0**
Immobilized Disposition -25% post-closure weight	***0.69***	***8.3***
Immobilized Disposition -75% post-closure weight	***0.68***	***8.1***
DIRECT DISPOSITION		
Disassembly & Conversion Facility	**0.82**	**9.8**
Deep Borehole Disposal Facility	**0.76**	**9.1**
Post-Closure ES&H Performance	**0.50**	**6.0**
Direct Disposition - 25% post-closure weight	***0.70***	***8.4***
Direct Disposition - 75% post-closure weight	***0.57***	***6.8***

2.3.2 Technical Unknowns and Risks

Technical unknowns for borehole disposition center around underground conditions and postclosure processes. It is believed that suitable rock formations can be found in a variety of areas, that they can be adequately characterized and the long term evolution of processes predicted to assure long term isolation and safety. However, this has not been demonstrated, and will not be until implementation of this concept. Most of these unknowns are represented in the Borehole R&D Plan submitted to the FMDP office or the Borehole Siting Guidance Report just completed and currently in review. Qualitatively, these unknowns are similar to those for disposal of spent MOX fuel or Pu immobilized as high-level radioactive waste, as a SNF/HLW repository has never been sited, fully characterized or licensed in this or any other country.

This direct borehole alternative differs somewhat from the immobilized borehole alternative in the area of technical unknowns. Directly emplacing the plutonium saves the cost of immobilizing but results in more uncertainties in long term isolation safety and a more complicated licensing safety argument. Thus, this alternative is slightly higher in uncertainty than immobilized disposal.

Technical risk follows from the primary uncertainties. This alternative would be many years into implementation before unexpected problems due to unanticipated underground conditions or processes would be discovered. This risk could be mitigated by early exploratory field studies to confirm or refute anticipated underground conditions and processes.

2.3.3 Assessment of Existing Regulatory Framework

Regulatory uncertainty is the largest single question remaining for borehole viability. This has been discussed in a Borehole Regulatory White Paper provided by LLNL to the FMDP office, in a Regulatory Plan prepared for the FMDP office by Fluor Daniel, and in the National Academy Reports on Pu disposition. The regulatory plan is being followed to interact with potential regulators to develop mutual agreement as to the viability of regulatory solutions to these uncertainties. Preliminary discussions with a variety of knowledgeable persons give both confidence and precedent that solutions can indeed be developed given sufficient time, or a social and congressional mandate. Certain of these issues are qualitatively similar for most or all of the disposition alternatives.

Regulatory Framework

Because concentrated, separated fissile material in significant quantities has never been considered for direct disposition before, many current waste management regulations are not clearly appropriate for such a facility. This implies a need for federal legislation to specify regulatory jurisdiction over any disposition activities for excess weapons usable fissile material. Development of a deep borehole facility would have its own unique regulatory uncertainties, primarily in the areas of siting, licensing and long term isolation and safety.

It is useful to consider the possible status of excess weapons-usable fissile material. Plutonium by itself is not either low-level waste (LLW) or high-level waste (HLW) as defined by regulation. It certainly is transuranic, but does not fit the common description of transuranic waste (TRU), which includes items that have been contaminated as a result of activities associated with the production of nuclear weapons such as rags, equipment, tools, contaminated sludges and residues. Significant quantities of concentrated plutonium also do not readily fit within the WIPP Waste Acceptance Criteria for TRU disposal. To meet the WIPP criteria, weapons usable plutonium would require dilution down into millions of barrels for emplacement as contact handled waste, or thousands of containers for remote handled waste which would consume much of the currently proposed capacity of the facility. This cursory analysis suggests that direct disposition of surplus fissile material might create a new category or sub-category of waste.

It has been noted that the congress, courts and regulatory bodies have shown willingness to act to specify jurisdiction and develop appropriate regulations to deal with safe disposition of nuclear materials. The Low Level Waste Policy Act of 1980, the Nuclear Waste Policy Act of 1987 and amendments in 1992, the WIPP Land Withdrawal Act and pending bills S.167 and HR1020 illustrate precedent for legislative action on nuclear material disposition issues. Regulations specific to HLW disposal, TRU disposal and even uranium mine tailing management have evolved. The DOE continues to move away from self regulation into compliance with regulation from NRC, EPA and other agencies. Because concentrated plutonium has never been considered waste and does not conform to definition or acceptance criteria for any waste form currently regulated, it is entirely appropriate to expect specific legislative and regulatory action to guide fissile material disposition.

Licensing and Siting

Licensing requirements are a key area for which there are no clearly applicable regulations for the deep borehole. Concentrated plutonium disposition forms meet neither the requirements for HLW or the normal criteria for TRU. It has been suggested that the HLW regulations of 10 CFR 60 Disposal of High-Level Wastes in Geologic Repositories could be used, but upon inspection there are significant mismatches both technically and legally between these regulations and the borehole facility mission which would preclude application of Part 60. For example, Part 60 includes provisions for subsystem performance requirements on waste packages and the engineered barrier system which are inappropriate for the safety argument for the borehole. Part 60 mandates a retrievability period which is inconsistent with the goal of timely disposition of weapons-usable materials. The time frames of various requirements of Part 60 are based on the radionuclide decay characteristics of spent nuclear fuel (SNF) and defense high-level waste (DHLW), which is inconsistent with the borehole disposition forms. Provisions of Part 60 pertain to manned access of require access to the operations area which is inconsistent with borehole emplacement. The licensing in Part 60 is actually several steps (following site characterization and selection per 10 CFR 960), an initial step of construction authorization followed by an operational authorization and later approval for final closure. This process acknowledges that much of the site specific data and long term performance confidence for the system will be obtained from the manned access and monitoring of the operational time period, and reflects the mandated retrievability of the emplaced waste. These considerations do not apply to an unmanned borehole concept with lack of retrievability as a desired feature. Thus one step licensing may be more appropriate for a borehole facility. Portions of Part 60 deal with thermal and radiation emissions from SNF and DHLW, which are inappropriate for plutonium. Portions of Part 60 dealing with criticality might be usable, but should be assessed in the safety context of the borehole concept. Finally, Part 60 was developed to assure safety of a much larger inventory of much more radioactive material in a facility much closer to the accessible environment than the borehole. Part 60 results from the Nuclear Waste Policy Act, which does not discuss excess weapons usable fissile material. In summary, it does not appear that 10 CFR 60 is directly appropriate for use in the context of deep borehole disposition.

The licensing regulations for WIPP have also been suggested for use in the context of the borehole. Safety compliance criteria for WIPP (40 CFR 194) were developed to comply with 40 CFR 191 and are based on the WIPP acceptance criteria which would not cover the weapons-usable disposition forms under consideration for the deep borehole unless they were partitioned and diluted. Further, the family of WIPP regulations was effectively customized in negotiating the land withdrawal act, and are specific to the WIPP mission, waste forms and location in bedded salt.

Both the HLW repository and WIPP provide useful precedent that governing legislation and regulations for licensing a plutonium disposition facility can and should be specifically developed for the mission. We observe that each nuclear disposal facility type other than LLW has resulted in legislation to specify jurisdiction and custom regulations for licensing and environmental protection. It is likely that much of the intent and structure of the HLW and WIPP regulations would serve as useful guides in such development, providing that the specific technical provisions were kept relevant to the mission and safety strategy for the borehole disposition facility.

Siting guidelines are another area of uncertainty. It has been suggested that site suitability guidelines such as those of 10 CFR 960 for the HLW repository program might be useful guidance for borehole siting. However, it is important to note that the HLW guidance was developed specifically for a mined geologic repository with human access for characterization, and for a facility for isolation of material posing a much greater dose hazard than the excess fissile material and with specific system and subsystem performance requirements. Many of the provisions of Part 960 are not be appropriate for the borehole facility. The intent of the guidance, however, could be used in formulating specific guidelines for siting and characterization of a borehole site consistent with the performance strategy for that facility. The FMDP deep borehole task has completed a study of potential site characteristics, the beneficial and adverse impacts which could result from these characteristics and existing capabilities for site characterization *(Heiken et al., August 1996).* The results from these preliminary studies should provide a basis for defining site selection guidelines in the future.

2.4 ENVIRONMENTAL, SAFETY AND HEALTH

2.4.1 Disassembly & Conversion Facility

The wastes and emissions generated and released during normal operations, during construction and during accidents by Disassembly and Conversion Facilities, and their ES&H consequences, are presented in the Draft PEIS (i.e., *Draft Programmatic Environmental Impact Statement for Storage and Disposition of Weapons-Usable Fissile Materials (February, 1996))* for the Direct Deep Borehole Disposition Alternative. However, certain differences that exist between the facilities considered in the Draft PEIS and in this report make it difficult to either directly apply, or to consider as bounding, the results presented in the Draft PEIS.

A major difference between the Disassembly & Conversion Facility given here and the corresponding Pit Disassembly/Conversion and Plutonium Conversion Facilities in the Draft PEIS is that the throughput and operating period of the two sets of facilities are very different. The current Disassembly & Conversion Facility is designed to process pit and non-pit feed materials at 5 t Pu/yr over a 10 year period. The Pit Disassembly/Conversion Facility in the Draft PEIS processes pits at the rate of 2 t Pu/yr over a 15 year period and the Plutonium Conversion Facility in the Draft PEIS processes non-pit feed materials at the rate of 0.4 t Pu/yr over a 20 year period. Thus, the plutonium processing throughput of the current Disassembly & Conversion Facility is approximately double that of the facilities considered in the PEIS.

In addition to the scheduling differences that will alter ES&H impacts from those given in the Draft PEIS, there are differences in the processes included in the facilities and how the facilities are sited. The Disassembly, Conversion and Immobilization Facility accepts pits, clean metals, impure metals, impure oxide, Pu alloys, alloy reactor fuels, oxide reactor fuels, clean oxide, impure oxide, U/Pu oxide, oxide-like materials, sand, slag & crucibles, and halide salts as feed to the Disassembly & Conversion process. Oxide-like materials, sand slag & crucibles, halide salts/oxides are expected to be converted to impure oxides as part of the DNFSB recommended 94-1 stabilization program in which case impure oxides would be processed instead by the facility. All of these feed materials are converted in this facility either to Pu-metal or to Pu oxide. After pit disassembly and special recovery, the disassembled pits are converted to Pu metal ingots using the hydride-dehydride process. Clean and impure metals, Pu-alloys, and decladded alloy reactor fuels, are simply reduced in size and are added to the Pu metal product stream for packaging. Halide salts/oxides are sent through a halide-wash and are converted to oxide by pyrolysis. Clean and impure oxides, U/Pu oxide, oxide-like materials, and oxide reactor fuels (after decladding and size reduction) are added to the Pu oxide product stream for packaging.

In contrast, the Draft PEIS assumes separate Pit Disassembly/Conversion and Pu Conversion Facilities. In the Pit Disassembly/Conversion Facility the pits are processed into both Pu metal and Pu oxide through hydride-dehydride and hydride-oxidation process steps whereas only the hydride-dehydride process for conversion to Pu metal is needed. All non-pit feed materials are processed into Pu oxide by the Pu Conversion Facility. This facility has a hydride-oxidation process step for Pu metals and aqueous separation/purification processes for certain impure mixed feeds. In the combined Disassembly & Conversion Facility presented in the current report, redundant and unnecessary processes have been eliminated and/or combined and the separate facilities have been consolidated into a single facility at a single site. For example, hydride-oxidation in non-pit Pu conversion, aqueous recovery lines and process steps for oxide purification, and separation of plutonium from uranium, have been eliminated. In addition to the benefits of process simplifications, elimination of the infrastructure of one entire site will yield a significant reduction in the total wastes and emissions below those analyzed in the Draft PEIS.

Consequently, the “front end” facilities and processes described here represent significant improvements over those given in the Draft PEIS, but they operate over a much shorter period at higher plutonium processing rates. Therefore, the wastes and emissions estimates given in the Draft PEIS are not directly representative of the actual wastes and emissions from the Disassembly & Conversion Facility described here.

2.4.1.1 Wastes and Emissions From Normal Operations and Construction

Wastes and Emissions during Operation

- *Chemical & Radiological Emissions:* Moderate amounts of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases, and 500 nCi/yr of radiological emissions are released by the Disassembly & Conversion Facility during operations.

- *High-Level Wastes:* There is no high-level radioactive waste generated from operation of the Disassembly & Conversion Facility.

- *Transuranic Wastes:* Transuranic wastes will be generated from process and facility operations, equipment decontamination, failed equipment and used tools. Transuranic wastes are treated onsite in a waste handling facility to form grout or compact solid waste. Treated transuranic waste products are packaged, assayed, and certified prior to shipping to the Waste Isolation Pilot Plant (WIPP) for disposal.

- *Low-Level Wastes:* Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

- *Mixed Transuranic Wastes:* A small quantity of solid mixed waste, mainly rubber gloves and leaded glovebox gloves from the waste handling facility, will be generated during operations of the Disassembly & Conversion Facility. The mixed waste is packaged and shipped to another DOE waste management facility (e.g., INEL at Idaho) for temporary storage, pending final treatment and disposal.

- *Mixed Low-Level Wastes:* Mixed wastes generated from the facility with radioactivity levels below the transuranic (TRU) waste level (100 nCi/g) will be classified as mixed low-level wastes and will be treated in the same manner as the mixed transuranic wastes described in the previous section.

- *Hazardous Wastes:* Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

- *Nonhazardous (Sanitary) Wastes:* Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

- *Nonhazardous (Other) Wastes:* Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

Wastes and Emissions During Construction

- *Emissions:* Land disturbance, vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption (for chemical pollutants) emissions are generated during construction activities.

- *Radioactive Wastes:* There may be radioactive wastes generated during construction of the Disassembly & Conversion Facility since the site is assumed to be an existing site.

- *Hazardous Wastes:* Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

- *Nonhazardous Wastes:* Solid nonhazardous wastes generated from construction activities (e.g., construction debris and rock cuttings) are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

2.4.1.2 Accident Mitigation, Accident Scenarios and Accidental Releases

The Disassembly & Conversion Facility is a Hazard Category 1 facility as defined in *DOE-STD-1027-94.* As such, it will require a detailed safety analysis report and risk assessment under *DOE Order 5480.23*. This section provides a brief description of the accident categories and summarizes a preliminary set of accidents postulated for each category in a summary Table. The summary of each accident includes the following elements:

- An estimate of the frequency of the scenario based on engineering judgment because the design of the facility is not advanced enough to justify use of rigorous risk analysis techniques,
- An estimate of the amount of radioactive material at risk in the accident based on the block flow diagrams and the equipment lists,
- An estimate of the fraction of material at risk that becomes airborne in respirable form based on the information collected in *Walker, (1981)* and *NUREG-1320 (1988),* and
- An estimate of the fraction of material airborne in respirable form that is removed by filtration of the ventilation system.

Based on these postulated accidents and on DOE and NRC guidance, the following systems, structures, and components (SSCs) in the Disassembly & Conversion Facility are assumed to be safety class items:

- Structures housing plutonium (per *DOE Order 6430.1A 1300-3.2* since collapsing or breaching these structures could result in an unconfined release of radioactivity with unacceptable consequences). The Plutonium Processing Building will be designed and constructed to withstand the forces of a Design Basis Earthquake (DBE) and all postulated facility accidents without building failure or significant cracking. Because of this design approach, confinement can be considered to be provided by the seismically qualified building and ventilation systems that isolates the building from the environment in emergency situations.

- Primary confinement is provided by the glove box system and the associated zone air handling system. Operations involving nuclear material are carried out within the glove boxes of the Plutonium Processing Building.

- Ventilation system(s) required to maintain confinement following an accident (per *DOE 6430.1A 1300-3.2* since loss of confinement could result in an unmitigated release of radioactive material and per *DOE 6430.1A 1300-7.2* which requires that at least one confinement system be designed to withstand the effects of severe natural phenomena and man made events). Air in the glove boxes and in the glove box air supply and exhaust gas system comprise Zone 1. Air in the process rooms external to the glove boxes is monitored continuously for airborne contamination. Air at the exit of Zone 1 filtration is also monitored continuously for contamination, and a high levels of radioactivity in the Zone 1 exhaust is cause for Zone 1 shutdown and Facility evacuation. Loss of Zone 1 flow or negative pressure is cause for immediate Facility shutdown.

- Other items required for criticality safety including monitoring equipment required to assure that plutonium and nuclear poison concentrations are within limits and the criticality alarm system (*DOE Order 6430.1A 1300-3.2*)

- Effluent monitoring equipment required to assess releases of radioactivity to the environment during and following a DBA (*DOE Order 6430.1A 1300-3.2*)

- Emergency power and UPS systems (as required for the SSCs to perform their safety functions per *DOE 6430.1A 1330-3.2*).

- Gloveboxes containing plutonium in powder form (Seismic Category I per *NRC Regulatory Guide 3.14*). Glove boxes will be standardized in single or multiple sections. Standard connectors on each end of a glove box provide for changing glove box trains while minimizing contamination. Standard glove boxes will have one-eighth inch lead encased in the glovebox walls to shield operating personnel from exposure to gamma rays. The interior of the glove boxes will have a smooth finish with no cracks or crevices and all welds will be ground smooth to blend with the surrounding metal. The window, glove port penetrations, and air lock closures will limit leakage through the seals to a level that is consistent with process requirements. Glove boxes will be made of stainless steel, and all parts inside the box will be easily accessible. Glove box ports for gloves will be welded into the glove box. Gloves will be made of a material appropriate to their usage, usually a lead-laminated rubber composite. Windows will be made of laminated safety glass with leaded glass installed on the outside as required. Window size will be minimized. All window seal gaskets will have a metal fire shield on the inside of the box to retard burnout and keep the window in place if the gasket is lost. Gloves and windows will be designed to be replaced without spreading contamination.

- The support structure of the boxes will be designed to meet Performance Category 1 seismic criteria. Glove box trains will be separated from each other and from conveyors by gravity operated fire dampers. Dampers separating the glove box lines from the conveyor system will be normally open. A heat sensing system (which will cause the breaking of a fusible link) will close the damper automatically in case of a fire.

- Plutonium storage and process containers, including tankage and piping, that are not contained in DBE resistant gloveboxes (Seismic Category I per *NRC Regulatory Guide 3.14*).

- Redundant fire water supplies and pumping capabilities (electric motor drivers with diesel back-up) will be installed to supply the automatic and manual fire protection systems located throughout the site. One supply and one set of pumps will be designed to meet DBE requirements. Appropriate types of fire protection systems will be installed to provide life safety, prevent large-loss fires, prevent production delay, ensure that fire does not cause an unacceptable on-site or off-site release of hazardous material that will threaten the public health and safety or the environment, and minimize the potential for the occurrence of a fire and related perils.

- Where potential for nuclear criticality exists, the design of the plant will include the basic controls for assuring nuclear criticality safety. Designs will satisfy the double contingency principle, i.e., ‘process designs shall incorporate sufficient safety factors so that at least two unlikely, independent, and concurrent changes in process conditions must occur before a criticality accident is possible’ from DOE 6430. lB. Basic control methods for the prevention of nuclear criticality include: provision of safe geometry, engineered density andlor mass limitation, provision of fixed neutron absorbers, provision of soluble neutron absorbers, and use of administrative controls. Although geometric controls are used extensively wherever practical, there are cases where geometric control alone cannot practically provide assurance of criticality safety. In these cases, engineered controls can be used to control moderation, nuclear poisons, mass, and density.

Bounding Accident Categories

The accidents postulated for nuclear facilities can be divided into three categories depending on the accident initiator: natural phenomena events, external events, and internal events. The following sections describe accidents in each of theses categories considered for this assessment. Table 2.4.1.2-1 summarizes the accident scenarios and releases for Operational and Design Basis Accidents and Beyond Design Basis Accidents.

Operational and Design Basis Accidents

In the Operational and Design Basis Accident category, natural phenomena are considered applicable to the Disassembly & Conversion Facility and are treated as design basis events are earthquakes, tornados and flooding. Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the Disassembly & Conversion Facility site. Such events would be addressed in the future if warranted by the site selected for the facility. External events in this category are events originating off-site. They are site specific and are not considered at this stage of conceptual design.

External events that will be addressed in the future include aircraft hazards, hazards from nearby facilities (explosions, missiles, chemicals), and transportation hazards (explosives, chemicals). The internal events considered as accident scenarios are: glovebox fire, glovebox criticality, dissolver spill, and the loss of off-site power.

Beyond-Design-Basis Accidents

In the Beyond-Design-Basis category, only external and internal event initiated accidents are considered; natural phenomena are excluded. External events originating offsite are site-specific and are not considered at this stage of conceptual design. Beyond-design-basis external events will be addressed in the future. Internal Events considered are: sintering furnace explosion, uncontrolled chemical reaction, plutonium storage criticality, plutonyl nitrate tank criticality and pellet storage criticality.

Table 2.4.1.2-1: Disassembly & Conversion Process Postulated Accident Summary

Accident	Frequency (DOE-STD-3005-YR)	Source	Respirable Airborne Fraction	Fraction of Source Released
DESIGN BASIS ACCIDENTS				
Earthquake	Extremely unlikely	20 kg Pu	10^{-3}	10^{-9}
Tornado	Extremely unlikely	No release	N/A	N/A
Flood	Extremely unlikely	No release	N/A	N/A
Glovebox Fire	Extremely unlikely	20 kg Pu	10^{-3}	10^{-9}
Glovebox Criticality	Extremely unlikely	10^{18} fissions	1 noble gases .25 halogens	1 noble gases .25 halogens
Combustibles waste loading dock fire	Unlikely	18 g Pu	5×10^{-4}	1.1×10^{-3}
PuO_2 Can Run Over & Breached	Unlikely	4 kg	284 mCi	1.2 nCi
Loss of Off-Site Power	Anticipated	No release	N/A	N/A
BEYOND DBAs				
Uncontrolled Chemical Reaction	Incredible	14 kg Pu	10^{-1}	10^{-9}
Pu Storage Criticality	Incredible	10^{18} fissions	1 noble gases .25 halogens	1 noble gases .25 halogens

2.4.1.3 ES&H Consequences of Normal Operations

The consequences of normal operations at the Disassembly & Conversion Facility on safety and health of the environment and people must be evaluated to be able to assess the Deep Borehole Disposition Alternative against the ES&H criterion. The ES&H consequences and associated risks for each separate facility (as configured in the Draft PEIS) are given in the Draft PEIS.

2.4.1.4 ES&H Consequences of Accidents

The consequences of operational accidents at the Disassembly & Conversion Facility on the safety and health of the environment and people must be evaluated to be able to assess the Deep Borehole Disposition Alternative against the ES&H criterion. The ES&H consequences and associated risks for each separate facility (as configured in the Draft PEIS) are given in the the Draft PEIS.

2.4.2 Deep Borehole Disposal Facility

The wastes and emissions generated and released during normal operations, during construction and during accidents by the Deep Borehole Disposal Facility, and their ES&H consequences, are presented in the Draft PEIS (i.e., *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement (Tetra Tech, Inc., February, 1996)*) for the Immobilized Deep Borehole Disposition Alternative. Because there are no differences between the facilities considered in the Draft PEIS and in this report, the results presented in the Draft PEIS can be directly applied to the Deep Borehole Disposal Facility.

2.4.2.1 Wastes and Emissions From Normal Operations and Construction

Wastes and Emissions During Operation

The annual wastes and emissions released during operation of the Deep Borehole Disposal Facility are estimated in the following subsections. A 10-year emplacement operation schedule is assumed.

- *Chemical Emissions:* The main air pollutant emissions from operation of the Deep Borehole Disposal Facility are derived from fuel and gas consumptions. Chemical processes which may lead to the release of contaminant over time are unlikely in the abbreviated times associated with the canister emplacement, backfill and stemming barrier processes. More likely are mechanical accidents where the containment capsules (canisters) are breached.

- *Radiological Emissions*: Estimated radiological release to environment during operation of the Deep Borehole Disposal Facility is shown in Table 2.4.2.1-2. The estimated release is based on the total curie inventory of radionuclides stored and processed annually in the Deep Borehole Disposal Facility with the radioactivity release factor from a previous design report (DOE/ET-0028) for plutonium storage facility, which has very similar operational characteristics to the Deep Borehole Disposal Facility.

- *High-Level Wastes:* There is no high-level radioactive waste generated from operation of the Deep Borehole Disposal Facility.

- *Transuranic Wastes:* Transuranic wastes will be generated from process and facility operations, equipment decontamination, failed equipment and used tools. Transuranic wastes are treated on-site in a waste handling facility to form grout or compact solid waste. Treated transuranic waste products are packaged, assayed, and certified prior to shipping to the Waste Isolation Pilot Plant (WIPP) for disposal.

- *Low-Level Wastes:* Low-level wastes generated from operations of the Deep Borehole Disposal Facility are treated with sorting, separation, concentration, and size reduction processes. Final low-level waste products are converted to solid form, surveyed for radioactivity, and shipped to a shallow land burial site for disposal.

- *Mixed Transuranic Wastes:* A small quantity of solid mixed waste, mainly rubber gloves and leaded box-gloves in the waste handling facility, will be generated from operation of the Deep Borehole Disposal Facility. The mixed waste is packaged and shipped to another DOE waste management facility (e.g., INEL at Idaho) for temporary storage, pending final treatment and disposal.

- *Mixed Low-Level Wastes:* Mixed wastes generated from the Deep Borehole Disposal Facility with radioactivity level below transuranic level (100 nCi/g) will be classified as mixed low-level wastes and will be treated in the same manner as the mixed transuranic wastes described in the preceding paragraph.

- *Hazardous Wastes:* Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricant for drilling and emplacement machinery. Hazardous wastes will be managed and hauled to commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

- *Nonhazardous (Sanitary) Wastes:* Non-hazardous sanitary liquid wastes generated in the Deep Borehole Disposal Facility are transferred to an on-site sanitary waste system for treatment. Non-hazardous solid wastes, such as domestic trash and office waste, are hauled to offsite municipal sanitary landfill for disposal.

- *Nonhazardous (Other) Wastes:* Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in catch tank and sampled before reclaim for other recycle use or release to the environment.

The combined waste from the drilling, emplacement consists of rock cuttings, bentonite and polymers used during drilling. These wastes will all end up in the mud pits. It is customary within the drilling industry to leave all of these wastes in the mud pits rather than ship them off site. After drilling is complete, the pits are generally filled up with earth and leveled. There is expected to be no treatment of these wastes unless testing indicates otherwise. The rock cuttings are shown in the table only as a volume since the rock will vary in density.

Wastes And Emissions Generated During Construction

The estimated wastes and emissions generated during construction of the Deep Borehole Disposal Facility are given in the following sections. A 3-year construction schedule is assumed.

- *Emissions:* Land disturbance, vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption (for chemical pollutants) emissions are generated during construction activities.

- *Radioactive Wastes:* There are no radioactive wastes generated during construction of the Deep Borehole Disposal Facility.

- *Hazardous Wastes:* Hazardous wastes generated from construction activities, such as motor oil, lubricant, and drilling fluid from vehicles and drilling machinery, will be managed and hauled to commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

- *Nonhazardous Wastes:* Solid nonhazardous wastes generated from construction activities, (e.g., construction debris and rock cuttings), are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to off-site for treatment and disposal.

2.4.2.2 Accident Mitigation, Accident Scenarios and Accidental Releases

The Deep Borehole Disposal Facility is a Hazard Category 1 facility as defined in DOE-STD-1027-92. As such, it will require a detailed safety analysis report and risk assessment under DOE Order 5480.23 before the facility is licensed for operation. This section provides a brief description of the accident categories and summarizes a preliminary set of accidents postulated for each category in a summary Table. The summary of each accident includes the following elements:

- An estimate of the frequency of the scenario based on engineering judgment because the facility design is not advanced enough to justify use of rigorous risk analysis techniques,
- An estimate of the amount of radioactive material at risk in the accident based on the block flow diagrams and the equipment lists,
- An estimate of the fraction of material at risk that becomes airborne in respirable form based on the information collected in Walker, (1981) and NUREG-1320 (1988), and
- An estimate of the fraction of material airborne in respirable form that is removed by filtration of the ventilation system.

The accident scenarios considered in this analysis are postulated for the Pre-Closure operational phase of the deep borehole facility operation.

The Post-Closure phase requires long-term performance analyses that require a program of research to develop the necessary information. Therefore, this analysis is deferred to a future study. The quantitative full-scope risk assessment using system models for the Pre-Closure phase will be performed along with the SAR preparation stage in the development and design of the facility.

Based on these postulated accidents and on DOE and NRC guidance, the following systems, structures, and components (SSCs) in the facility are assumed to be safety class items:

- Structures housing plutonium (per DOE Order 6430.1A 1300-3.2 since collapsing or breaching these structures could result in an unconfined release of radioactivity with unacceptable consequences).
- Ventilation system(s) required to maintain confinement following an accident (per DOE 6430.1A 1300-3.2 since loss of confinement could result in an unmitigated release of radioactive material and per DOE 6430.1A 1300-7.2 which requires that at least one confinement system be designed to withstand the effects of severe natural phenomena and man made events).
- Other items required for criticality safety including monitoring equipment required to assure that plutonium and nuclear poison concentrations are within limits and the criticality alarm system (DOE Order 6430.1A 1300-3.2).
- Effluent monitoring equipment required to assess releases of radioactivity to the environment during and following a DBA (DOE Order 6430.1A 1300-3.2).
- Emergency power and uninterruptible power supply systems will be provided (as required for the SSCs to perform their safety functions per DOE 6430.1A 1330-3.2).
- The Deep Borehole Disposition Facility will be sited at a geologic location with low seismicity (Seismic Zone 1 according to the Uniform Building Code with a maximum acceleration level of 0.075g). Process equipment will be fastened by bolt or tied down to reduce earthquake damage. Activity released is removed by HEPA filters.
- Tornado dampers will be installed in the surface processing building and the process building will be constructed to meet the safety criteria in DOE-STD-1020-94.
- The surface process building will be constructed above the flood line to preclude flooding in plutonium storage and process area in accordance with DOE-STD-1020-94.
- Low seal stress is maintained in the storage container to minimize the occurrence of breakage. Ventilation system is isolate and monitored for plutonium contamination. Activity released is removed by HEPA filters.
- The disposal form containers will be designed to survive accidents. Administrative procedure controls will be established for extremely careful container handling to reduce the likelihood of this kind of accident. Radioactive materials released are removed by HEPA filters.
- The disposal form shipping package will be designed with double container to survive transportation accidents.

- Facility design will include fire suppression system and fire isolation barriers in the process areas. Minimum quantity of combustible material in the process areas will be maintained by administrative controls. Activity released is removed by HEPA filters.
- Process areas with high potential of spill will be plated with stainless steel for ease of decontamination and leak proofing. Activity released is removed by HEPA filters.
- Facility will be designed with emergency diesel generators and uninterruptible power system (UPS) for safety critical system controls and operations.
- A canister string could be dropped by the crane as a result of major structural failure or operator error. A free falling canister string could get stuck and/or rupture in the isolation zone of the borehole. Appropriate design safety factors, single point fail-safe hoists, stringent QA/QC fabrication procedures, dead-man systems, clutch-brake interlocks, periodic non-destructive testing and evaluation of critical components, and administrative safety procedures will be implemented to mitigate such accidents.

Bounding Accident Categories

The accidents postulated for nuclear facilities can be divided into three categories depending on the accident initiator: natural phenomena events, external events, and internal events. The following sections describe accidents in each of theses categories considered for this assessment. Tables 2.4.2.2-1 and 2.4.2.2-2 summarize the accident scenarios and releases for Operational and Design Basis Accidents and Beyond Design Basis Accidents, respectively. More detailed descriptions of these accident scenarios can be found in *Wijesinghe et al. (January 15,, 1996d).*

Operational and Design Basis Accidents

In the Operational and Design Basis Accident category, natural phenomena are considered applicable to the Deep Borehole Facility and are treated as design basis events are earthquakes, tornados and flooding. Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the facility site. Such events would be addressed in the future if warranted by the site selected for the facility. External events in this category are events originating off-site. They are site specific and are not considered at this stage of conceptual design. External events that will be addressed in the future include aircraft hazards, hazards from nearby facilities (explosions, missiles, chemicals), and transportation hazards (explosives, chemicals). The internal events considered as accident scenarios are: Pu storage container breakage during storage, Pu storage container breakage during handling, emplacement canister dropped during handling, on-site emplacement canister transportation accident, criticality during emplacement canister filling, criticality during Pu storage container spill, fire in facility process area, failure of ventilation blower, failure of ventilation filter, loss of electrical power, canister string dropped during emplacement - ruptured in emplacement zone, canister string dropped during emplacement - ruptured and stuck in isolation zone, canister string stuck in emplacement zone, canister string stuck in isolation zone and emplacement facility electrical fire.

Table 2.4.2.2-1: Summary of Design Basis Accident Scenarios and Release Fractions

ID	Accident Scenario	Accident Frequency[1]	Source Term at Risk	Respirable Fraction	Fraction Released
1	Earthquake	Extremely Unlikely	N/A	No release	No release
2	Tornado	Extremely Unlikely	N/A	No release	No release
3	Flood	Extremely Unlikely	N/A	No release	No release
4	Pu Storage Container Breakage During Storage	Unlikely, 10^{-5} /container/year	4.5 kg Pu	10^{-5}	10^{-13}
5	Pu Storage Container Breakage During Handling	Unlikely, 10^{-6}/handling	4.5 kg Pu	10^{-3}	10^{-11}
6	Emplacement Canister Dropped During Handling	Unlikely, 10^{-6}/handling	40.5 kg Pu	No release	No release
7	On-Site Emplacement Canister Transportation Accident	Unlikely, 1.6×10^{-6} /truck km	40.5 kg Pu	No release	No release
8	Criticality During Emplacement Canister Filling	Extremely Unlikely	10^{19} prompt fissions in 8 hrs noble gas and halogen fission products release	1.0 noble gas 0.25 halogen	1.0 noble gas 0.25 halogen
9	Criticality During Pu Storage Container Spill	Extremely Unlikely	10^{19} prompt fissions in 8 hrs noble gas and halogen fission products release	1.0 noble gas 0.25 halogen	1.0 noble gas 0.25 halogen
10	Fire in Facility Process Areas	Extremely Unlikely	40.5 kg Pu	10^{-3}	10^{-9}
11	Failure of Ventilation Filter	Anticipated	N/A	No release	No release
12	Failure of Ventilation Blower	Anticipated, 0.5/year	N/A	No release	No release
13	Loss of Electrical Power	Anticipated, 1/year	N/A	No release	No release

[1] Corresponds to terminology defined in DOE-STD-3009-94

Descriptive Word	*Annual Frequency*
Anticipated	$10^{-1} \geq p > 10^{-2}$
Unlikely	$10^{-2} \geq p > 10^{-4}$
Extremely Unlikely	$10^{-4} \geq p > 10^{-6}$
Beyond Extremely Unlikely	$10^{-6} \geq p$

Table 2.4.2.2-1: Summary of Design Basis Accident Scenarios and Release Fractions (Continued)

ID	Accident Scenario	Accident Frequency[1]	Source Term at Risk	Respirable Fraction	Fraction Released
14	Canister String Dropped During Emplacement - Ruptured in Emplacement Zone	Extremely Unlikely	1012.5 kg Pu	4.0×10^{-5}	4.0×10^{-13}
15	Canister String Dropped During Emplacement - Ruptured and Stuck in Isolation Zone	Extremely Unlikely	1012.5 kg Pu	2.4×10^{-7}	2.4×10^{-13}
16	Canister String Stuck in Emplacement Zone	Extremely Unlikely	1012.5 kg Pu	No Release	No Release
17	Canister String Stuck in Isolation Zone	Extremely Unlikely	1012.5 kg Pu	No Release	No Release
18	Emplacement Facility Fire - Electrical	Extremely Unlikely	1012.5 kg Pu	No Release	No Release

[1] Corresponds to terminology defined in DOE-STD-3009-94

Descriptive Word	*Annual Frequency*
Anticipated	$10^{-1} \geq p > 10^{-2}$
Unlikely	$10^{-2} \geq p > 10^{-4}$
Extremely Unlikely	$10^{-4} \geq p > 10^{-6}$
Beyond Extremely Unlikely	$10^{-6} \geq p$

Table 2.4.2.2-2: Summary of Beyond Design Basis Accident Scenarios and Release Fractions

ID	Accident Scenario	Accident Frequency[1]	Source Term at Risk	Respirable Fraction	Fraction Released
1	Uncontrolled Chemical Reaction	Beyond Extremely Unlikely	N/A	No Release	No Release
2	Pu Container Criticality in Storage	Beyond Extremely Unlikely	10^{19} prompt fissions in 8 hrs noble gas and halogen fission products release	1 noble gas .25 halogen	1 noble gas .25 halogen
3	Emplacement Canister Criticality in Storage	Beyond Extremely Unlikely	10^{19} prompt fissions in 8 hrs noble gas and halogen fission products release	1 noble gas .25 halogen	1 noble gas .25 halogen
4	Criticality of Canister Contents at Bottom of Emplacement Zone upon Rupture of Dropped Canister String	Beyond Extremely Unlikely	10^{19} prompt fissions in 8 hrs noble gas and halogen fission products release	1 noble gas .25 halogen	1 noble gas .25 halogen

[1] Corresponds to terminology defined in DOE-STD-3009-94

Descriptive Word	*Annual Frequency*
Anticipated	$10^{-1} \geq p > 10^{-2}$
Unlikely	$10^{-2} \geq p > 10^{-4}$
Extremely Unlikely	$10^{-4} \geq p > 10^{-6}$
Beyond Extremely Unlikely	$10^{-6} \geq p$

Beyond Design Basis Accidents

In the Beyond-Design-Basis category, only external and internal event initiated accidents are considered; natural phenomena are excluded. External events originating offsite are site-specific and are not considered at this stage of conceptual design. Beyond-design-basis external events will be addressed in the future. Internal Events considered are: uncontrolled chemical reaction, Pu container criticality in storage, emplacement canister criticality in storage and criticality of canister contents at bottom of emplacement zone upon rupture of dropped canister string.

2.4.2.3 ES&H Consequences of Normal Operations

The consequences of normal operations at the Deep Borehole Disposal Facility on safety and health of the environment and people must be evaluated to be able to assess the Deep Borehole Disposition Alternative against the ES&H criterion. The ES&H consequences and associated risks have been evaluated for this facility and are given in the Draft PEIS.

2.4.2.4 ES&H Consequences of Accidents

The consequences of operational accidents at the Deep Borehole Disposal Facility on the safety and health of the environment and people must be evaluated to be able to assess the Deep Borehole Disposition Alternative against the ES&H criterion. The ES&H consequences and associated risks have been evaluated for this facility and are given in the Draft PEIS.

2.5 COST OF THE DEEP BOREHOLE DISPOSITION ALTERNATIVE

The total undiscounted Life Cycle Cost of the Direct Deep Borehole Disposition Alternative is 2.6 $B US dollars. The top-level breakdown of this total cost by facility and cost-phase is given in the following Table 2.5-1.

Table 2.5-1: Cost Summary for the Direct Deep Borehole Disposition Alternative

Cost $M	Disassembly & Conversion	Deep Borehole Disposal	Total End-to-End Alternative
Total Up-Front Cost	**244**	**865**	**1,109**
Total Operating Cost	**804**	**671**	**1,475**
Total life cycle costs	**1,048**	**1,536**	**2,584**

This Deep Borehole Disposition Alternative represents a medium performance (from criticality safety, environmental safety and health and disposition security points of view) moderate cost alternative in the suite of deep borehole disposition alternatives we considered. The total life cycle cost of this alternative is about 990 $M (27.7%) less than that of the Immobilized Deep Borehole Disposition Alternative.

General Approach to Cost Estimation

The approach to costing the Direct Deep Borehole Disposition Alternative is a life cycle cost (LCC) methodology. Costs are developed for the total overall project including initial R&D, licensing/permitting, design, construction, operation and final decommissioning. These costs are then analyzed and plotted against the end-to-end alternative schedule to provide constant dollar cash flows which can then be discounted at the appropriate real discount rate. The two major figures-of-merit for each alternative are the following: 1) the constant dollar front end costs, that is, all life cycle costs prior to normal operation of each facility (this is what the Government must spend to develop, design, construct, and start-up a given facility), and 2) the total life cycle costs, which include all ‘cradle to grave’ project costs paid by the Government and include front-end costs, revenues (if any), recurring costs, and end-of-life costs.

A ‘lump sum’ constant dollar cost for each major facility was developed using a ‘bottoms-up’ approach. This ‘bottoms-up’ approach involves defining process flow sheets in sufficient detail such that major process operations are well identified. Then a list of major and supporting equipment is generated for each major process operation. Process operation data is developed for the items on this list and include batch size, process cycle time, manpower requirements per process cycle, installed equipment cost estimates, and equipment size, space and ventilation requirements. A Pu balance is then determined for a given processing rate assumption which in turn is used to calculate the quantity of equipment and number of equipment operating cycles necessary to meet the assumed production schedules. Based on the required equipment list, equipment cost and size data, and standardized scaling algorithms, it is possible to estimate the size and cost of the Pu processing facility required for these operations. The algorithm employed for this study utilized the PUPP model originally developed for the Complex 21 costing and sizing studies and adapted to the facility requirements for the Pu disposition processing. Manpower requirements were calculated based on the number of operating cycles, manpower requirements data per cycle, and scaling algorithms contained in the adapted version of PUPP.

Conceptual design and Title I, II, and III costs were calculated based on the facility complexity and equipment and facility cost estimates above. R&D, NEPA, and contingency, and facility start-up costs were then added to complete the front end cost estimate. Recurring cost estimates included salaries for direct and support personnel, facility maintenance, supplies, other consumables, and transportation. Final D&D costs estimates based on the facility complexity and capital investment were also made. Total lifetime costs were estimated in constant dollars by adding the front end costs, recurring costs over the lifetime of the facility, and final D&D costs.

Schedule considerations are considered elsewhere and only affect the way in which the lump sum costs are 'spread' over time. Each lump sum cost, however, must have a baseline schedule which is compatible..

2.5.1 Disassembly & Conversion Facility Costs

Table 2.5.1-1 shows the major operating assumptions for the Disassembly & Conversion Facility which performs only non-hot cell operations. Since such an operation is dominated by the shipping/receiving and recovery operations, we assume that all non-hot cell operations will be contained in a single Pu facility. Specific examples include all recovery operations and all immobilization operations not involving the use or radionuclide spikes such as ^{137}Cs or high level waste. Such operations require similar glove box and ventilation systems as those used for the recovery operations and would normally be combined.

Among the costing assumptions adopted here is that the Pu processing operations of this Disassembly & Conversion Facility will be located in an available existing Category I building (221F) at DOE's Savannah River Site. Consequently, the cost of this building and supporting plant utilities is excluded from the cost estimate.

Table 2.5.1-1: Pu Processing Assumptions for the Disassembly & Conversion Facility

Assumptions	
Plant capacity	5 t Pu/yr
Average plant throughput	25 kg Pu/day
Plant location	Existing DOE Site at SRS 221F Category I Facility Used
Plant owner	U.S. Government (DOE)
Process building type	Seismic Category 1 for Pu handling areas
NEPA, safety, permitting & oversight	DOE/DNFSB
Feedstocks	Pits and other surplus Pu forms
Product Material	Pu metal or oxide
Plant operational lifetime / total Pu processed	10 years / 50 t Pu
Time from start of Title I to hot startup	7.5 years
Data source for cost information	LLNL

The facility sizing and cost estimates were developed using the cost estimating procedure outlined above and are based on the second level flowsheets for this facility. R&D costs are those for the specific operations identified on the second level flowsheets which can be performed in a standard Pu processing facility (e.g., no hot cell operations, only glove box operations). Post construction start-up costs are estimated as 1.5 years of operating costs based on the anticipated start-up schedule. Waste disposal costs are based on Pu throughput and are costed at $10,000 per drum for TRU waste and $2,000 per drum for LLW. Table 2.5.1-2 shows the summary of the Disassembly & Conversion Facility Pu processing costs.

Table 2.5.1-2: Life Cycle Cost Summary for the Disassembly & Conversion Facility

COST ITEM DESCRIPTION	Cost $M	COST BASIS
UP-FRONT COSTS:		
"PREOPERATIONAL COSTS		
1. R&D	46	
2. NEPA Licensing & Permitting	6	
3. Conceptual Design	5	
4. Q/A, Site Qualification, S&S	2	
5. Post-Construction Start-up	50	
6. Risk Contingency (From Uncertainty Anal.)	15	
SUB-TOTAL	**124**	
UP-FRONT "CAPITAL" COSTS		
7. Title I, II, III Engineering, Design & Inspection	20	
8. Capital Equipment	40	
9. Facility Construction	40	
10. Construction Management	4	
11. Initial Spares (Technology Dependent)	2	
12. Allowance for indeterminates (AFI)	14	
13. Risk Contingency (From Uncertainty Anal.)	0	
SUB-TOTAL	**120**	
TOTAL UP-FRONT COST	**244**	
OPERATING COSTS (Total 10 year costs)		
14. Operations & Maintenance Labor	370	
15. Consumables	90	
16. Maintenance and Spares	150	
17. Waste Handling & Disposal	40	
18. Oversight	10	
19. M&O Contractor fees	20	
20. PLT to Local Communities	10	
21. D&D (At closure)	64	
22. Govt. Subsidies or Fees to Private Facilities	0	
23. Transportation of Pu Forms to Facility	50	
24. Storage of Pu at Existing 94-I Site Facility	0	
TOTAL OPERATING COSTS	**804**	
GRAND TOTAL LIFE CYCLE COST	**1,048**	

2.5.2 Deep Borehole Disposal Facility Costs

Table 2.5.2-1 shows the major assumptions upon which the Deep Borehole Disposal Facility design and costs are based. This facility handles non-hot cell Pu operations at the deep borehole site.

Table 2.5.2-1: Pu Processing Assumptions for the Deep Borehole Disposal Facility

Assumptions	
Plant capacity	5 t Pu/yr
Average plant throughput	25 kg Pu/day
Plant location	Generic **Deep Borehole Disposal** Site
Plant owner	U.S. Government (DOE)
Process building type	Seismic Category 1 for Pu handling areas
NEPA, safety, permitting & oversight	DOE/DNFSB
Feedstocks	Pu metal or oxide
Product material	Borehole disposal of 40.5 kg of Pu/canister (38 cm (15 in.) ID x 6.1 m (20ft)long) grouted into the borehole
Plant operating time / total Pu processed	10 years / 50 t Pu
Time from start of Title I to hot startup	9.5 years
Borehole drilling time	4 years
Data source for cost information	LLNL and Bechtel

The Deep Borehole Disposal Facility costs are estimated at a preconceptual level. The deep borehole facility site is assumed to be located at an unspecified generic site located centrally in the continental United States.

The estimates are made for comparative analysis of life cycle costs of various options of fissile material disposal and establish the basis of more accurate costs for Phase III. The cost estimates were developed by an architect engineer firm under contract for this study and are based on the second level flowsheets, defined process equipment required for these operations, and cost estimates based on the AE experience in similar construction with DWPF and other engineering operations.

Cost escalation is excluded in the estimate. The estimates also assume a normal schedule without delays. Cost exclusions are cost of land, roads and utilities outside fence line. R&D costs are those required for the specific operations associated primarily with the subsuface operations, site chracterization and performance assessment activities required to support the design and licensing of the Deep Borehole Disposal Facility. NEPA, site qualification, and post construction start-up were estimated based on the total complexity, size, and cost of the estimated facility. The details of the cost estimating are outlined below:

The capital cost estimates are based on costs of major process equipment, process support systems, utility and service systems, plant buildings and site requirements. The method of estimating is based on the following:

- ***Major Process systems*** - equipment cost including cost per item plus factored cost of bulk materials (piping, etc.)
- ***Process support systems*** - equipment costs (where available), allowances or capacity and size x factor
- ***Utility and service systems*** - capacity and size x factor
- ***Plant buildings (facilities)*** - pre-conceptual quantity takeoffs, HVAC, special features (lined cells, etc.) or $\$/m^2$ or $\$/m^3$.

The capital cost estimate includes direct costs, indirect field costs, total field costs, contractors costs and profit, construction management, A-E cost, management costs, initial spares, and contingency. The operating cost estimates include operating and maintenance staffing costs, consumables, maintenance and spares, and waste handling and disposal costs. Table 2.5.2-2 shows the summary of the costs for Pu-loaded coated ceramic pellet disposal at the Deep Borehole Disposal Facility.

2.5.3 Deep Borehole Site Characterization Costs

The siting process is a key element in selecting a site with adequate long-term performance. The process consists of two phases. First, large geologically suitable areas are screened and a few sites selected that will be further characterized. Since it is difficult to prove a site acceptable without detailed work, unsuitable areas will be screened out through use of existing regional studies. Suitable remaining sites will be studied in more detail, using non-invasive techniques such as surface mapping, surface sample analysis, and geophysical surveys. The first phase is therefore an effort to locate areas likely to have favorable characteristics without disqualifiers.

When it is determined that there are no disqualifiers for a site, the second site-specific investigation phase is begun. It is expected that several candidate sites will be chosen. At each, a small diameter pilot corehole will be drilled. The core from the hole will be subjected to extensive laboratory testing. The hole itself will be geophysically logged and results tied into the surface geophysical surveys. Fluid analysis and hydrologic testing on the hole will determine if favorable isolation conditions are present. Drilling parameters will be measured and used to fine tune the drilling program for the emplacement holes if the site is chosen. Additional site data will be obtained as each large diameter emplacement hole is cored and drilled. Cross-hole hydrologic and geophysical testing will be performed on each additional hole, as well as the standard logging as performed on the pilot hole. Details of the testing program for each phase are described below and the components of each activity are listed in Tables 2.5.3-1 and 2.5.3-2

Table 2.5.2-2: Life Cycle Cost Summary for the Deep Borehole Disposal Facility

COST ITEM DESCRIPTION	Cost $M	COST BASIS
UP-FRONT COSTS:		
"PREOPERATIONAL " COSTS		
1. R&D	62	
2. Conceptual Design	22	10% of Capital Construction Cost
3. Site Screening, Selection & Characterization	237	
4. Performance Assessment	37	
5. Land Acquisition	5	
6. NEPA Licensing & Permitting	75	
7. Q/A, Site Qualification, S&S	4	
8. Post-Construction Start-up	27	50% of Annual Operating Cost
9. Risk Contingency (From Uncertainty Anal.)	117	25% of (1 to 8)
SUB-TOTAL	**587**	
UP-FRONT "CAPITAL" COSTS		
10. Title I, II, III Engineering, Design & Inspection	38	
11. Capital Equipment	73	
12. Facility Construction	98	
13. Construction management (% of category 8)	13	6% of Capital Construction Cost
14. Initial spares (Technology Dependent)	1	2% of Capital Equipment Cost
15. Allowance for Indeterminates (AFI)	0	
16. Risk Contingency (From Uncertainty Anal.)	55	25% of (10 to 15)
SUB-TOTAL	**278**	
TOTAL UP-FRONT COST	**865**	
OPERATING COSTS (Total 10 year costs)		
17. Operations & Maintenance Labor	274	Drilling, Processing & Emplacing
18. Consumables	198	
19. Maintenance and Spares	58	
20. Waste Handling & Disposal	16	
21. Oversight	5	
22. M&O Contractor Fees	11	
23. PLT to Local Communities	6	
24. D&D (At closure)	28	10% of Capital Construction Cost
25. Govt. Subsidies or Fees to Private Facilities	0	
26. Transportation of Pu Forms to Facility	75	
27. Storage of Pu at Existing 94-I Site Facility	0	
TOTAL OPERATING COSTS	**671**	
GRAND TOTAL LIFE CYCLE COST	**1,536**	

together with the budget for each task. These site-specific tests in this second phase are designed to determine if the rock mass has been functionally isolated for geologic time spans, and if the isolation can be maintained for long time scales.

1. ***Site Screening:*** Site screening will begin after the ROD and will continue for 2 years. Its purpose is to evaluate large geographic domains, and subsequently successively smaller and increasingly more suitable domains, for features favorable to the containment and isolation of weapons excess fissile materials. The process will consider the merits and shortcomings of domains against geologic and non-geologic guidelines that provide a reasonable basis for assessment. The result of evaluation will be a list of potentially acceptable sites.

2. ***Site Selection:*** Site Selection will begin 2 years after the ROD and will continue for approximately 2 years. The purpose of this activity is to collect and evaluate evidence required to support the nomination of a site as suitable for characterization. The source of information for this activity will include literature and related studies, exploratory boreholes, surface investigations, rock testing at repository conditions, and the extrapolation of regional data to estimate site-specific characteristics and conditions. Technical evaluations will provide additional bases for evaluating the ability of a site to meet the qualifying conditions of siting guidelines. The nomination of a site as suitable for characterization will be based on an environmental assessment as specified in the Nuclear Waste Policy Act Amended (NWPA). The bases and relevant details of those evaluations and of the decision processes involved therein will be contained in the environmental assessment for the site. The result of the evaluation will the nomination of at least three sites suitable for site characterization.

3. ***Nominated Site Assessment***: Assessment of the nominated sites will begin 4 years after the ROD and will continue for approximately 4 months. The purpose of this activity is to prepare a recommendation for submission by the Secretary of the DOE to the President of not less than three candidate sites for characterization. Sites nominated as suitable should be considered as to their order of preference as candidate sites for characterization. Sites recommended as candidate sites should offer the most advantageous combination of characteristics and conditions for the successful development of repositories at such sites.

4. ***Site Characterization:*** Characterization of the candidate sites will begin 4.33 years after the ROD and will continue for 4 years. The purpose of this activity is to gather data from the candidate sites for comparing the sites according to post-closure and pre-closure assessment guidelines, similar in context to 10CFR960 Subparts C and D, but developed exclusively for applicable qualifying conditions for a deep borehole repository. This activity will be coordinated with the pre-operational performance assessment task that is budgeted as a separate activity. This comparison will lead to a recommendation by the Secretary to the President of a site for the development of a repository. The Secretary will make public a statement of the basis of such recommendation pursuant to the requirements of the Nuclear Waste Policy Act Amended (NWPA). A separate site selection EIS will be prepared in parallel with the characterization activities, if deemed necessary. The environmental impact statement will include the results of the comparative evaluation and a description of the decision process that resulted in the selection of the candidate site for development of such repository.

Table 2.5.3-1: Site Screening and Site Selection Costs for the Deep Borehole Disposition Alternative ($M)

SITE SCREENING	1997	1998	1999	2000	2001	Total
1. Regional Geologic Assessment	**0.60**	**0.60**				**1.19**
2. Regional Non-Geologic Impacts	**0.58**	**0.58**				**1.15**
3. Identification of Candidate Sites	**0.00**	**0.39**				**0.39**
TOTAL ANNUAL COST	**1.17**	**1.56**				**2.73**
SITE SELECTION	**1997**	**1998**	**1999**	**2000**	**2001**	**Total**
1. Meterological Studies			**0.17**	**0.04**		**0.21**
2. Environmental Studies			**0.20**	**0.08**		**0.29**
3. Socioeconomic Studies			**0.21**	**0.08**		**0.28**
4. Transportation Studies			**0.16**	**0.06**		**0.21**
5. Exploratory Boreholes			**51.60**	**14.37**		**65.97**
5.1 Borehole drilling			47.90	8.93		**56.83**
5.2 Lithologic Logging			3.12	0.65		3.77
5.3 Hydrologic & Geophysical Testing			0.45	3.68		4.13
5.4 Laboratory Testing of Core Samples			0.09	0.69		0.78
5.5 Chemical Analyses of Water Samples			0.05	0.43		0.47
6. Surface Investigations			**0.21**	**0.02**		**0.22**
6.1 Geologic Mapping			0.08	0.01		0.09
6.2 Geophysical Surveys			0.12	0.01		0.13
7. Rock Mechanics at Emplacement Zone Conditions			**0.69**	**0.35**		**1.04**
8. Emplacement Zone Modeling			**0.04**	**0.12**		**0.17**
9. Extrapolation of Regional Data			**0.25**	**0.05**		**0.30**
10. Site Nomination for Characterization			**0.08**	**0.33**		0.41
11. Site Recommendation for Characterization					**0.37**	
TOTAL ANNUAL COST			**53.61**	**15.48**	**0.37**	**69.46**

Table 2.5.3-2: Site Characterization Costs for the Deep Borehole Disposition Alternative ($M)

SITE CHARACTERIZATION	2001	2002	2003	2004	2005	Total
1. Characterization for Post-Closure Performance	**23.87**	**34.11**	**34.11**	**30.77**		**122.87**
1.1 Waste Containment and Isolation Requirements	2.34	3.34	3.34	3.02		12.04
1.2 Geohydrologic Setting	3.67	5.25	5.25	4.73		18.90
1.3 Geochemical Characteristics	2.19	3.12	3.12	2.82		11.26
1.4 Rock Characteristics	1.09	1.54	1.54	1.39		5.56
1.5 Climate Changes	2.34	3.34	3.34	3.02		12.04
1.6 Erosion Processes	1.67	2.39	2.39	2.15		8.59
1.7 Subsurface Rock Dissolution	0.74	1.04	1.04	0.95		3.78
1.8 Future Tectonic Processes	4.17	5.97	5.97	5.38		21.48
1.9 Commercially Extractable Resources	3.67	5.25	5.25	4.73		18.90
1.10 Site Ownership and Control	2.00	2.86	2.86	2.58		10.31
2. Characterization for Pre-Closure Performance	**7.98**	**11.44**	**11.44**	**10.29**		**41.15**
2.1 Radiological Safety						
2.1.1 Population Density	0.28	0.40	0.40	0.36		1.43
2.1.2 Site Ownership and Control	0.05	0.07	0.07	0.06		0.24
2.1.3 Meteorology	0.49	0.71	0.71	0.63		2.53
2.1.4 Offsite Installations and Operations	0.38	0.54	0.54	0.48		1.94
2.2 Environment, Socioeconomics and Transportation						
2.2.1 Environmental Quality	1.76	2.52	2.52	2.27		9.06
2.2.2 Socioeconomic Impacts	1.24	1.78	1.78	1.60		6.39
2.2.3 Transportation System	1.50	2.15	2.15	1.93		7.72
2.3 Technical Feasibility of Siting Options						
2.3.1 Surface Characteristics	0.26	0.36	0.36	0.33		1.31
2.3.2 Rock Characteristics	0.68	0.98	0.98	0.89		3.52
2.3.3 Hydrology	0.76	1.08	1.08	0.98		3.89
2.3.4 Tectonics	0.61	0.87	0.87	0.78		3.13
3. Site Recommendation for Repository Development	**0.17**	**0.17**	**0.25**	**0.33**	**0.10**	**1.01**
TOTAL ANNUAL COST	**32.02**	**45.71**	**45.80**	**41.39**	**0.10**	**165.02**

The total annual cost for each major siting activity is given in Table 2.5.3-3. The total annual cost and the total cumulative cost of all siting activities are also given in this summary table.

Table 2.5.3-3: Total Siting Costs for the Deep Borehole Disposition Alternative ($M)

Siting Activity	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total
Site Screening	1.17	1.56								**2.73**
Site Selection	0	53.61	15.48	0.37						**69.46**
Site Characterization					32.02	45.71	45.80	41.39	0.10	**165.0**
Total Annual Cost	**1.17**	**55.16**	**15.48**	**0.37**	**32.02**	**45.71**	**45.80**	**41.39**	**0.10**	
Total Cum. Cost	**1.17**	**56.33**	**71.82**	**72.19**	**104.2**	**149.9**	**195.7**	**237.1**	**237.2**	

2.5.4 Intersite Transportation Costs

Intersite transportation costs for the Direct Deep Borehole Disposition Alternative are given in Table 2.5.4-1. The equipment for handling the transportation packages at the Feed Originating, Disassembly & Conversion and Deep Borehole Disposal Facilities are considered to be facility capital costs and are not included in Table 2.5.4-1 as transportation costs. Furthermore, O&M staffing and maintenanc/testing costs associated with these package handling activities are also considered to be facility costs. Approximately 10 FTEs will be required for this purpose during disposition operations.

Table 2.5.4-1: Intersite Transportation Costs for the Direct Deep Borehole Disposition Alternative ($M)

Cost Category	Cost $M
NEPA Licensing	3.3
Q/A Site Qualification	1.6
Capital[1]	18.2
O&M Staffing[2]	18.1
Waste Handling/Disposal	1.5
D&D	11.4
SST Transportation	44.5
TOTAL	**80.5**

[1]Handling equipment, and their maintenance/testing are facility costs.
[2]O&M Staffing for package handling is a facility cost.

2.5.5 Integrated R&D Program Costs

The Integrated R&D Program costs for the Direct Deep Borehole Disposition Alternative for the disposition of weapons-useable surplus fissile material are given Table 2.5.5-1 by Major Activity Area and Technology Sub-Area. The plan requires five years

Table 2.5.5-1: Research & Development Program Costs for the Direct Deep Borehole Disposition Alternative ($M)

R&D Program Element	1997 $M	1998 $M	1999 $M	2000 $M	2001 $M	Total $M
3. BOREHOLE DISPOSAL						
3.1 Performance Assessment	0.64	1.34	2.21	3.61	4.60	**12.40**
3.2 Site Characterization	0.52	1.05	2.04	5.24	5.82	**14.67**
3.3 Materials Characterization	0.52	1.16	2.27	3.49	3.38	**10.83**
3.4 Engineering and Operations	0.93	2.10	3.43	7.86	9.78	**24.10**
SUBTOTAL	***2.62***	***5.65***	***9.95***	***20.20***	***23.58***	***62.00***
7 PIT DISASSEMBLY						
7.1 Disassembly	1.30	2.08	1.30	0.00	0.00	**4.68**
7.2 Adv. System for Plutonium Removal from Pits	0.74	0.97	0.74	0.00	0.00	**2.46**
7.4 Nondesctructive Assay System	0.65	0.46	0.46	0.00	0.00	**1.58**
7.5 Oralloy Decontamination	0.48	0.80	0.70	0.00	0.00	**1.98**
7.6 Spent Part Declassification	0.46	0.28	0.28	0.00	0.00	**1.02**
SUBTOTAL	***3.63***	***4.60***	***3.48***	***0.00***	***0.00***	***11.71***
8. PLUTONIUM CONVERSION						
8.1 Separation	2.04	2.94	1.98	0.91	0.23	**8.10**
8.2 Stabilization	2.05	1.76	1.39	0.28	0.00	**5.48**
8.3 Conversion	0.37	1.02	1.39	0.56	0.00	**3.34**
8.4 Waste Management	0.83	2.02	2.50	1.40	0.83	**7.59**
SUBTOTAL	***5.29***	***7.74***	***7.26***	***3.14***	***1.07***	***24.50***
9. PLUTONIUM STORAGE						
9.1 Plutonium Storage Criteria	2.27	1.90	1.90	0.46	0.00	**6.53**
9.2 Safety Surveillance	4.41	2.75	1.46	0.00	0.00	**8.63**
9.3 Safety Analysis	0.60	0.69	0.69	0.00	0.00	**1.99**
SUBTOTAL	***7.28***	***5.35***	***4.06***	***0.46***	***0.00***	***17.15***
13. SAFEGUARDS & SECURITY						
13.1 System Effectiveness Evaluation	1.59	2.23	1.96	0.75	0.00	**6.54**
13.2 International Safegfuards	1.36	1.96	1.16	0.82	0.77	**6.06**
13.3 Nuclear Materials Measurement Systems	1.04	0.77	0.23	0.00	0.00	**2.04**
SUBTOTAL	***3.99***	***4.96***	***3.35***	***1.57***	***0.77***	***14.64***
TOTAL ANNUAL R&D COST	**22.82**	**28.28**	**28.12**	**25.37**	**25.41**	**130.00**
TOTAL CUMULATIVE R&D COST	**22.82**	**51.10**	**79.22**	**104.59**	**130.00**	

for completion (1997 - 2001 assuming ROD on December 1, 1996) and covers the major activity areas of Borehole Disposal, Pit Disassembly, Plutonium Conversion and Safeguards and Security. The plan addresses only the R&D components of each of these areas; site selection, site characterization, performance assessment, materials characterization, engineering and operations, and safeguards and security activities that are not identified as R&D are separately budgeted. The R&D plan assumes that the siting process is a separate cost item not included in the plan. No sites are assumed for the technology demonstration tests. However, if a site is available, portions of the R&D plan costs will contribute towards site characterization costs. Although no full depth-full diameter borehole demonstration test will be performed prior to final site selection, the plan includes a full depth-narrow diameter borehole demonstration test for site characterization R&D and a partial depth-full diameter borehole demonstration test for drilling, emplacing and borehole sealing technology demonstration tests. The annual R&D plan cost breakdown is given in Table 2.5.5-1.

2.6 SCHEDULE

2.6.1 Schedule Overview

The preliminary nominal schedule to site, license, deploy, operate, and decommission/close an integrated system for the deep borehole disposal of surplus weapons Pu in the form of oxide or metal is presented in Figure 2.6.1-1. The schedule assumes a start date of January 1, 1997, which is consistent with the current December, 1996 scheduled date for the record of decision (ROD). Disposition begins 10 years after the ROD in 2007, and continues for 10 years until the end of 2016. All activities at the site, including D&D, are completed by the end of 2018.

The schedules are divided into three time periods: preoperational, operational, and postoperational. The preoperational period comprises all licensing and permitting activities necessary to operate the system, as well as research and development (R&D), site characterization, and facility design and construction of the Disassembly & Conversion and the Deep Borehole surface processing/underground facility. The operational period comprises the cold and hot operations of the Disassembly & Conversion and of the Deep Borehole Disposal Facility. This period begins upon the commencement of cold operations in the Disassembly & Conversion (9.5 years after ROD) and ends upon the completion of borehole emplacement operations (22 years after ROD). The postoperational period commences following the completion of hot operations at the Disassembly & Conversion Facility, and ends following complete decontamination, decommissioning (D&D), and closure of both the Disassembly & Conversion Facility and the Deep Borehole Disposal Facility.

Table 2.6.4-1: Timeliness Measures for Direct Deep Borehole Disposition

Timeliness Measure	Years From Project Start (1/1/1997)	Date
Start Emplacement	10	1/1/07
End Emplacement	20	12/31/16
Seal Last Borehole	20.5	6/30/17
Close All Sites	22	12/31/18

Nominal Implementation Schedule for the Direct Deep Borehole Disposition Alternative

ID	Task Name	Years	Start	Finish
1	TOTAL BOREHOLE LIFE CYCLE TIME	22	Sun 12/1/96	Mon 12/31/18
2	PRE-OPERATIONAL PERIOD	10	Sun 12/1/96	Sun 12/31/06
3	Deep Borehole (DBH) Facility	10	Sun 12/1/96	Sun 12/31/06
4	Legislation & Rulemaking	3	Sun 12/1/96	Fri 12/31/99
5	Record of Decision	0	Sun 12/1/96	Sun 12/1/96
6	Enabling Legislation	1.5	Wed 1/1/97	Tue 6/30/98
7	Pre-Rulemaking Discussions with NRC	1.5	Wed 1/1/97	Tue 6/30/98
8	NRC Rulemaking	1.5	Tue 6/30/98	Fri 12/31/99
9	DOE Determination of Site Suitability	1.5	Tue 6/30/98	Fri 12/31/99
10	Site Selection & Characterization	6	Wed 1/1/97	Tue 12/31/02
11	Site Screening	1	Wed 1/1/97	Wed 12/31/97
12	Site Nomination	1	Thu 1/1/98	Thu 12/31/98
13	Site Characterization	3	Tue 1/5/99	Mon 12/31/01
14	Research & Development	5	Fri 1/3/97	Mon 12/31/01
15	Site Selection EIS	3.25	Thu 10/1/98	Thu 12/27/01
16	DOE Site Determination	0	Mon 12/31/01	Mon 12/31/01
17	DBH Facility License Preparation	4	Mon 10/5/98	Tue 10/1/02
18	Public Notice of License Application	0.25	Tue 10/1/02	Tue 12/31/02
19	DOE Files DBH License Application	0	Tue 12/31/02	Tue 12/31/02
20	Borehole NRC Licensing Proceedings	3.75	Wed 1/1/03	Sat 9/30/06
21	NRC Review	1	Wed 1/1/03	Wed 12/31/03
22	NRC Issues SER	0	Wed 12/31/03	Wed 12/31/03
23	Discovery	1	Thu 1/1/04	Fri 12/31/04
24	Hearing by ASLB	0.75	Fri 12/31/04	Fri 9/30/05
25	Decision by ASLB	1	Mon 10/3/05	Fri 9/29/06
26	NRC Issues Borehole License	0	Sat 9/30/06	Sat 9/30/06
27	Environmental/NEPA/NRC for DBH	8	Tue 1/5/99	Sun 12/31/06
28	DOE Prepares Env. Report.	5	Tue 1/5/99	Wed 12/31/03
29	DOE Files Report with NRC	0	Wed 12/31/03	Wed 12/31/03
30	NRC Prepares & Issues DEIS	2	Fri 1/2/04	Sat 12/31/05
31	DEIS Comment Period	0.5	Mon 1/2/06	Fri 6/30/06
32	NRC Responds to Comments	0.5	Wed 7/5/06	Fri 12/29/06
33	NRC Issues Final EIS	0	Sun 12/31/06	Sun 12/31/06
34	DBH Facility Design & Construction	9	Wed 1/1/97	Fri 12/30/05
35	Conceptual Design	2.5	Wed 1/1/97	Wed 6/30/99
36	Title I, II Design	2.5	Fri 7/2/99	Mon 12/31/01
37	DBH Surface Facility Construction	4	Tue 1/1/02	Fri 12/30/05
38	Disassembly & Conver.(D&C) Facility	9	Wed 1/1/97	Sat 12/31/05
39	Permitting/Licensing	9	Wed 1/1/97	Sat 12/31/05
40	NEPA Activities & Permits	4	Wed 1/1/97	Fri 12/29/00
41	Prepare D&C License Application	2	Tue 1/2/01	Tue 12/31/02
42	Submit Application to NRC	0	Tue 12/31/02	Tue 12/31/02

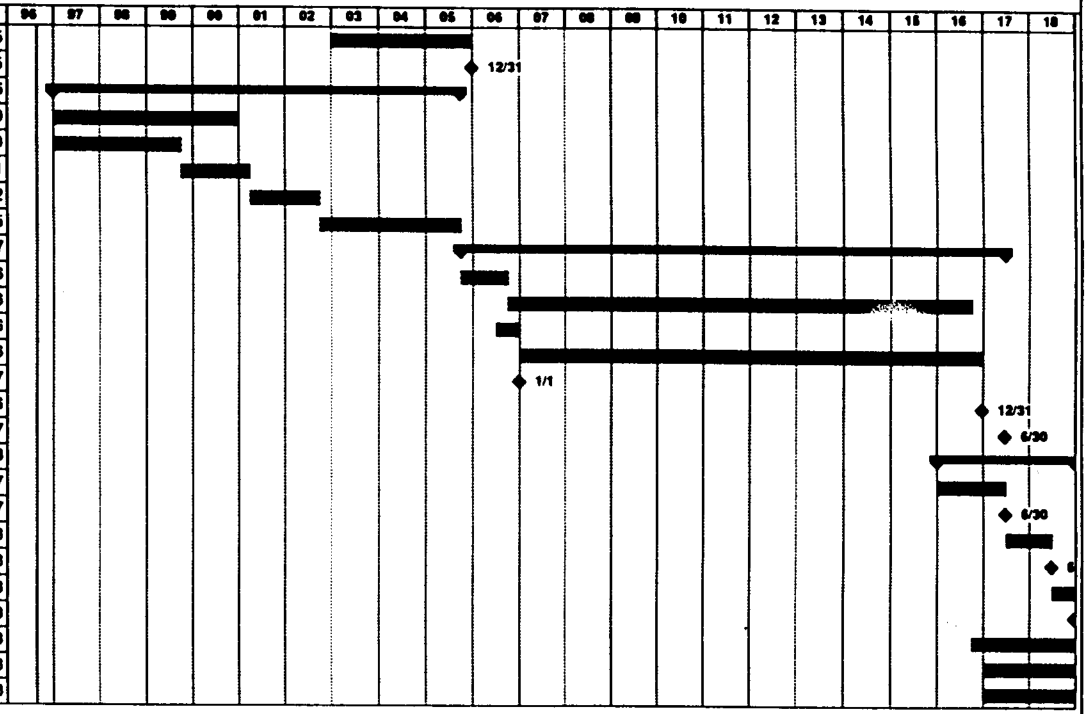
Project: Plutonium Disposition
Date: Fri 8/23/96

Task — Progress — Milestone — Summary — Rolled Up Task — Rolled Up Milestone — Rolled Up Progress

Figure 2.6.1-1: Nominal Implementation Schedule for the Direct Deep Borehole Disposition Alternative

Nominal Implementation Schedule for the Direct Deep Borehole Disposition Alternative

ID	Task Name	Years	Start	Finish
43	NRC Licensing	3	Wed 1/1/03	Fri 12/30/05
44	NRC Grants License	0	Sat 12/31/05	Sat 12/31/05
45	**Design & Construction**	**8.75**	**Wed 1/1/97**	**Fri 9/30/05**
46	Research & Development	4	Wed 1/1/97	Fri 12/29/00
47	Conceptual Design	2.75	Wed 1/1/97	Thu 9/30/99
48	Title I Design	1.5	Mon 10/4/99	Fri 3/30/01
49	Title II Design	1.5	Mon 4/2/01	Mon 9/30/02
50	Construction	3	Tue 10/1/02	Fri 9/30/05
51	**OPERATIONAL PERIOD**	**11.75**	**Mon 10/3/05**	**Fri 6/30/17**
52	D&C Facility Cold Operations	1	Mon 10/3/05	Fri 9/29/06
53	D&C Facility Hot Operations	10	Mon 10/2/06	Fri 9/30/16
54	DBH Facility Cold Operations	0.5	Fri 6/30/06	Fri 12/29/06
55	DBH Facility Hot OPerations	10	Wed 1/3/07	Fri 12/30/16
56	Start Emplacement	0	Mon 1/1/07	Mon 1/1/07
57	End Emplacement	0	Sat 12/31/16	Sat 12/31/16
58	Emplacement Complete	0	Fri 6/30/17	Fri 6/30/17
59	**POST-OPERATIONAL PERIOD**	**3**	**Mon 1/4/16**	**Mon 12/31/18**
60	DOE Prepares Amend. to Close DBH Facility	1.5	Mon 1/4/16	Fri 6/30/17
61	DOE Submits Amend. to Close DBH Facility	0	Fri 6/30/17	Fri 6/30/17
62	NRC Review	1	Tue 7/4/17	Fri 6/29/18
63	NRC Grants License to Close DBH Facility	0	Sat 6/30/18	Sat 6/30/18
64	DBH Facility Closure	0.5	Mon 7/2/18	Mon 12/31/18
65	DBH Facility Closure Complete	0	Mon 12/31/18	Mon 12/31/18
66	D&D of D&C Facility	2.25	Mon 10/3/16	Mon 12/31/18
67	D&D of DBH Facility	2	Mon 1/2/17	Mon 12/31/18
68	Post-Emplacement Monitoring	2	Mon 1/2/17	Mon 12/31/18



Project: Plutonium Disposition
Date: Fri 8/23/96

Task | Milestone ◆ | Rolled Up Task | Rolled Up Progress
Progress | Summary | Rolled Up Milestone ◇

Figure 2.6.1-1: Nominal Implementation Schedule for the Direct Deep Borehole Disposition Alternative (Continued)

2.6.2 Scheduling Issues

Pre-Operational period

- ***Legislation and Rulemaking:*** The legislative and regulatory framework for the disposition of surplus weapons Pu is not well established at the present time (see Section 2.3.3). In particular, the case of borehole disposal of radioactive materials was not under active consideration when the existing laws and regulations (*e.g.*, The Nuclear Waste Policy Act of 1982 as amended, and Title 10, Part 60 of the Code of Federal Regulations, both of which govern the disposal of HLW and commercial spent nuclear fuel) were promulgated. Thus, present laws and regulations will need, at the least, to be modified or amended to cover the disposal alternative described in this report. In keeping with this, a period of legislative activities and NRC rulemaking is shown in the schedule, during which time it is anticipated that a suitable set of regulations can be established. This is a critical path activity in the schedule. Informal discussions between the DOE, the NRC, and other interested parties occur over the 1.5-year period during which legislative action is presumed to occur.

- ***Borehole R&D, Site selection, and Site characterization:*** Non-site-specific research and development and site screening activities are carried out parallel with the legislative and rule making period. Final site selection, however, can only be carried out after rule making is complete. This activity falls on the critical path after final regulations have been established for deep borehole disposal of Pu. Site characterization and determination of site suitability follow site selection and are critical path activities. The preparation of a site-specific Environmental Impact Statement is undertaken in parallel with the site characterization activities. The preparation of a license application for operation of the borehole and associated surface facilities begins during the site characterization phase, and ends one year after the determination of site suitability. This critical-path activity culminates in the submission of a license application to the NRC to operate the Deep Borehole Disposal Facility. Six years elapse between the ROD and submission of the borehole license application.

- ***Borehole Licensing Proceedings:*** A key assumption in the FMD program is that any new facility would be licensed by the NRC. Thus, as a new facility, the Deep Borehole Disposal Facility will certainly fall under the regulatory purview of the NRC. As discussed above, and in more detail in the section on schedule uncertainties, below, the regulatory requirements applicable to the proposed borehole disposal system are not clearly established at this time. For the purposes of constructing the implementation schedule in this report, a reasonable approach to borehole licensing has been developed.

  The approach adopted here assumes that the DOE will characterize the selected site, and submit a single application to the NRC for permission to operate the borehole and surface facilities. Surface facility construction begins prior to the license. (A separate application would be submitted for the construction and operation of the front-end/Disassembly & Conversion Facility. See below.) The NRC staff would review the application and issue a SER. The ASLB would subsequently hold formal hearings on the matter. Time is allowed for a period of full discovery prior to the hearings. After the hearings, the ASLB will deliberate and issue a license to operate. This sequence of events and activities lies on the critical path for the nominal case, which allows 4 years from the time DOE submits a license until the time the NRC issues the license

- ***Environmental/NEPA for Borehole:*** It is assumed that a site-specific EIS will need to be prepared for the Deep Borehole Disposal Facility. The series of activities is shown as starting with the development by the DOE of the necessary environmental data. This activity runs in parallel with site characterization (and Title I design, see below). This information is submitted to the NRC somewhat before the DOE files for the borehole license application. Following the issuance of the SER for the Deep Borehole Disposal Facility by the NRC (see above), the NRC prepares and issues a draft EIS, which is made available for public comment. Additional time is scheduled for the NRC to respond to comments and prepare the final EIS. These activities, though necessary and important, are not on the critical path for either the accelerated or the nominal schedules.

- ***Borehole Design and Surface Facility Construction:*** Conceptual design of the Deep Borehole Disposal Facilities begins immediately after the ROD, and extends through site selection (4.5 years total). Once a site has been selected, Title I design begins, followed by Title II design (combined time of 3.75 years). The designs are complete in time for the DOE to incorporate them into the Deep Borehole Disposal Facility. Construction of the surface facilities begins after Title II design, and is completed 9 years after the ROD. None of these activities is on the critical path.

- ***Disassembly & Conversion Facility Licensing, Design, and Construction:*** The schedule for the Disassembly & Conversion Facility given in this report is taken directly from, and is consistent with, the more detailed schedule given in the Alternative Technical Summary Document for the Disassembly and Conversion front-end of the Ceramic Pellet Immobilization Alternative. No optimization of that schedule has been attempted here. This series of activities leading up to the cold startup of the Disassembly & Conversion Facility is on the critical path, and it is believed that the schedule presented for this case can be further compressed. Note that in order to achieve an overall reduction in the time before borehole emplacement of Pu can begin, it is not sufficient to compress the schedule for the Disassembly & Conversion Facility alone; the sequence of activities leading up to the licensing of the borehole must also be compressed in time.

Operational Period

The Operational Period begins with the start of operations in the Disassembly & Conversion Facility. Disassembly & Conversion activities start as soon as construction of the facility is complete and begin with a half-year cold operations period, followed by 10 years of hot operations in the nominal case. Similarly, the Deep Borehole Disposal Facility activities begin with a half-year of cold operations, followed by 10 years of hot emplacement operations. Disposition of material would be complete after 20 years. The 10-year operation period corresponds to the case analyzed in the PEIS.

Disassembly & Conversion and emplacement activities are on the critical path, and there is the potential for significant time savings if an accelerated program of processing and emplacement is undertaken. Experience gained during the cold operations and initial hot operations could also shorten the operational schedule. Note that the rate of operation of the borehole itself will be feed-rate limited in the nominal case; any reduction in the time required to immobilize the Pu can be directly utilized to decrease the time to completion of disposition subject to the limitation of sufficient time being allowed for borehole siting and licensing activities. An accelerated disposition case in which the disposition period was compressed into 3 years was considered. In this case, emplacement would be completed 15 years after the ROD and will result in a 9-year decrease in the overall time to complete disposition. Cost estimates have shown a moderate increase in cost over the 10 year disposition case due primarily to the larger throughput capacity of the Disassembly & Conversion Facility.

Post-Operational Period

The Post-Operational period overlaps with the Operational Period owing to the fact that hot operations will cease at the Disassembly & Conversion Facility before the actual Deep Borehole Disposal Facility disposition activities are complete. Although important, the Post-Operational activities do not impact the date at which disposition will be complete (*i.e.*, the date the last material is emplaced and sealed into a borehole). Actual decontamination and decommissioning (D&D) activities begin one year prior to the end of hot operations at the Disassembly & Conversion and Deep Borehole Disposal Facility. D&D activities at each of these facilities are scheduled to last for 2.25 and 2 years, respectively.

It is anticipated that the NRC will require some form of application to close the subsurface activities at the Deep Borehole Disposal Facility. The nature and content of such an application cannot be predicted with any certainty at this time. Nevertheless, a series of activities (application preparation, submission, NRC review, NRC decision) has been included during this period that leads to the granting of a license to close the Deep Borehole Disposal Facility. In addition, long-term environmental monitoring of the Deep Borehole Disposal Facility site will begin during the Post-Operational Period. This activity is arbitrarily shown to terminate at the end of the period, which coincides with completion of the D&D activities. In reality, the length of the monitoring activity will likely be specified by the NRC/EPA and may continue for decades after all other activities at the site have ceased..

2.6.3 Scheduling Uncertainties

The schedule presented in this section is a logic network defined by activity durations and logical ties between them. As such, it lends itself to an examination of the impacts in schedule variations. At this stage of planning, however, such an analysis has not been done. In addition, each activity is associated with a cost. Costs and schedules are intimately related, and changes in one will invariably affect the other. Both cost and schedule can and should be optimized subject to programmatic and fiscal constraints. Such an optimization has not yet been done, but it offers the possibility of reducing both the cost and time associated with the budget and schedule presented here. Conversely, budgetary constraints not considered here could lead to significant delays in the schedule presented in this document.

The major uncertainty associated with the schedule shown in Figure 2.6.1-1 involves the licensing approach for the Deep Borehole Disposal Facility. In particular, it is assumed that a single license will be granted to operate the facility. The approach adopted here is deemed reasonable; however, it differs from the one specified in 10 CFR 60 governing the licensing of a mined geologic repository. In the case of a repository, the DOE must first obtain a license to construct the repository. Then, after the surface facilities and sufficient underground excavations have been constructed to allow the emplacement of an initial quantity of waste, the DOE must then seek a license to operate the repository. Such a process may be referred to as a ‘two-step’ licensing procedure. If a similar two-step licensing process were adopted by the NRC for the case of the Deep Borehole Disposal Facility, the Pre-Operational Period could be lengthened by as much as six years, which would result in a year-for-year increase in the time before hot emplacement operations can commence.

It is believed that a two-step licensing procedure, while appropriate for a mined geologic repository, offers no additional protection for the public in the case of a Deep Borehole Disposal Facility. In the case of a mined geologic repository, considerable mining and construction activity is needed to construct the initial drifts, shafts, etc. of the repository after site characterization is completed. In contrast, in the case of the underground portion of a Deep Borehole Disposal Facility, the final stage of site characterization would almost certainly be the emplacement to target depth of a large diameter borehole that would be used as the first emplacement hole, Thus, by the end of the characterization period, the construction of the subsurface portion of the Deep Borehole Disposal Facility would be ‘substantially complete’ as defined by 10 CFR 60.41.

In this connection, it should also be noted that at the time of this writing, both Congressional and NRC actions are being contemplated that would change the procedure for licensing a geologic repository to a single-step process similar to the one assumed here for scheduling the Deep Borehole Disposition Alternative. It would appear that the process that has been outlined for the Deep Borehole Disposition Alternative is at least consistent with current regulatory and legislative thinking on licensing processes.

2.7 OTHER ISSUES

2.7.1 Benefits to Other Programs

Potential benefits to other programs would be secondary with this focused and custom designed disposition alternative, however a few possible benefits include:

- With development of a disposition facility specifically for concentrated fissile material, other waste management programs would be relieved of potential impacts, and could benefit from the borehole disposition capacity. Transuranic waste (TRU) disposal at a facility such as the Waste Isolation Pilot Plant (WIPP) would not be asked to extend capacity to handle excess weapons-usable material and could concentrate on the intended mission of low concentration waste management. The greater isolation offered by the borehole could possibly accept some of the more problematic wastes intended for WIPP and simplify the WIPP mission. Similarly, high-level radioactive waste (HLW) disposal facilities such as that proposed for Yucca Mountain, or a follow-on second repository, would be relieved of potential operational, licensing and capacity impacts and could focus on the intended HLW mission.
- With fielding of a deep borehole program, the technology of deep scientific research drilling, and deep resource exploitation could receive spin-off benefits.
- Successful disposition of excess plutonium in deep boreholes could lead the way for future disposal of other small volume, high isolation priority wastes in deep boreholes. This could include other high risk radionuclides (e.g., minor actinides), or highly toxic materials.
- It is likely that borehole disposition could utilize personnel, equipment and methods from the former underground weapons testing program. This would provide ongoing beneficial use of these existing resources, and maintain in a productive way, those capabilities (staff, equipment, competence in drilling, characterization, emplacement and stemming) which might be needed for future testing.

2.7.2 Cooperation with Russia

Based on interactions to date, Russian representatives have unambiguously articulated a preference for Pu ‘utilization’ alternatives (e.g., reactors) vs. Pu ‘disposal’ alternatives (e.g., deep boreholes). Yet, this does not preclude robust cooperation/collaboration in deep geologic disposal for the following reasons:

- It is expected that both Russian and U.S. inventories of surplus fissile materials will include materials which do not represent a viable ‘utilization’ resource. Particularly for this subset of the material inventory, deep borehole technology may offer sufficient promise to merit active cooperation in developmental activities.

- The borehole alternatives are the only ones (with the exception of the CANDU reactor option) independent of the federal waste management system. Cooperative work in this area with Russia could bolster the ‘robustness’ of the path forward for final disposition of surplus fissile materials.

- Contingent upon a national mandate to site and license a borehole facility, technical implementation of borehole disposition can be completed in a short time compared to many other alternatives. A rapid completion schedule for U.S. borehole disposition would provide an incentive for rapid Russian completion of a different, but comparably effective, ‘utilization’ disposition option.

2.7.3 Public and Institutional Acceptance

The principal public and institutional acceptance issues for this alternative (and the other deep borehole alternatives) are regulatory and licensing related. As with any of the disposition alternatives, local or regional opposition to the project will likely manifest itself in the regulatory and licensing process as well as other channels. The relative newness of the deep borehole concept may be a source of public and institutional concern and resistance. This will be partially, if not entirely, offset by the technical soundness and low risks of deep borehole disposition.

A borehole facility would be sited, developed and licensed in a open and public process. This would benefit greatly from a strong mandate for implementation. Such a mandate is possible based on the public consensus that elimination of large numbers of nuclear weapons in the U.S. and Russia is for the good of all mankind. There is considerable precedent for acceptance of otherwise undesirable facilities if they are clearly for the greater and common good. Seen as a key element in global disarmament, borehole disposition of weapon material could be a great opportunity, a peace initiative. Also, the inherent distinction of borehole disposition from commercial nuclear power activities and weapons testing and production is likely to be beneficial for public acceptance.

Deep borehole disposition complies with the national policy of geologic disposal of radioactive wastes and is consistent with international agreements on waste management. It is anticipated that this alternative will rank higher in this category than the other borehole alternatives due to minimal plutonium handling and processing.

3.0 OPPORTUNITIES FOR HYBRID ALTERNATIVES

Hybrid options have not been explicitly assessed at this point in the program, so possible pros and cons are speculative. However, the following opportunities for hybrid alternatives exist and should be studied further:

- ***Feed Splitting Based on Feed Quality:*** Borehole disposition appears particularly well suited to hybrid options in combination with MOX fueled reactors. Not all of the excess plutonium is readily or economically convertible to reactor fuel. A hybrid option would have the 'good' material converted to oxide reactor fuel and material with unsuitable isotopic or chemical composition, morphology, etc. being disposed in the borehole. This could eliminate costly processing of small quantities of Pu with special processing requirements. Either borehole alternative could work in such a hybrid. A variation of the direct borehole alternative might be capable of disposing of many materials without processing, thus saving considerable cost.

- ***Dual Use of Fuel Pellet Fabrication Facilities:*** The immobilized borehole alternative could use the MOX fuel facility to produce sintered pellets for borehole disposition and save immobilization facility costs, but would still require conversion of the non-fuel-useable Pu to oxide first. The borehole facility itself could gain from the reduced capacity requirement by reducing borehole numbers, depth or diameter, and by reducing the linear Pu loading factor which would reduce uncertainties in isolation and criticality safety. The reactor facility would benefit from only dealing with material which is economical to convert to fuel.

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5.0 GLOSSARY

Special Terminology

Bentonite: A naturally occurring highly impermeable and chemically sorptive clay material that contains the swelling clay material smectite. It can also contain quartz, mica, feldspar, and calcite.

Borehole Array area: The Northern part of the Deep Borehole Disposal Facility occupied by the borehole array and including the Drilling and Emplacing-Borehole Sealing Facilities.

Casing: Structure used to line the borehole and to prevent an inflow of material or water.

Cementing: The process of pumping a grout slurry either into the borehole or into the space between the borehole wall and the casing in borehole cementing operations.

Closure period: The period extending from the ending of the operation period to the completion of backfilling and sealing the deep boreholes and decontaminating, decommissioning of the facility as a whole, and making the facility ready to be placed on post-closure status.

Concrete: A mixture of cement, sand, water, sand (“fine aggregate”) and 0.635-2.54 cm (0.25-1.0 in) diameter solid particles called the “coarse aggregate.” Chemical additives such as water reducers, superplasticizers, swelling agents and materials such as silica fume and fly ash are often part of high-performance concrete formulations.

Construction period: The period extending from the beginning of construction activity to the commissioning of the deep borehole facility for acceptance of SFM waste for disposal.

Disposal form: A generic term applied to the physical and chemical form in which the plutonium material is emplaced in the borehole. For example, this could be Pu metal or PuO_2 in transportation containers or ceramic coated Pu-loaded ceramic pellets.

Disposition option: Any one of a number of alternatives identified for burning in reactors or permanently disposing of weapons-usable excess fissile materials. These include geologic disposal in a mined geologic repository after immobilization in a disposal form in combination with high-level nuclear waste, using as fuel in special reactors to partially convert to non-fissile fission products and disposing of the spent fuel in a mined geologic repository, and geologic disposal in a deep borehole without combining with radioactive waste.

Drilling Facility: One or more drilling units each consisting of a drill rig, associated mud and water pumps, cementing trucks, storage tanks, stand-by generator, mud-pits, personnel trailers etc. as shown in the Drilling Facility Plot Plan.

Emplacing-Borehole Sealing Facility: One or more disposal form emplacing and borehole sealing units consisting of a crane for canister emplacing, canister assembly sub-base, cementing trucks, pumps, waste treatment plant and personnel trailers, etc. as shown in the Emplacing Facility Plot Plan.

Emplacement canister: A metal canister in which a disposal form is emplaced within the borehole in canistered disposal options.

Emplacement zone: The bottom part of a deep borehole (2 km) where the disposal form is emplaced.

Grout: Specially formulated cement/sand/water mixtures with chemical additives. Differs from concrete by the absence of coarse aggregate material. Used for hydraulic sealing of void spaces.

High-level nuclear waste: Highly radioactive fission products resulting from reactor operations and nuclear fuel reprocessing that has radioactivity exceeding certain regulatory radiation limits.

Isolation zone: The upper part of a deep borehole (2 km.) extending from the top of the emplacement zone to the ground surface used to seal and isolate the emplaced disposal form from the biosphere.

Kaolinite: A naturally occurring highly impermeable and chemically sorptive clay material that contains the swelling clay material smectite. It can also contain quartz, mica, feldspar, and calcite. CHANGE THIS!!!!

Main Facility: The Southern part of the Deep Borehole Disposal Facility that includes all facility buildings and storage areas excluding the Borehole Array in the Northern part. This includes the Surface Processing Facility, the Utility Support Facility, the Plant Waste Management Facility, the Central Warehouse, the Administration offices, Security, ES&H and Medical Centers, the Fire Station and the personnel services building.

Mud: The fluid used in the drilling process. Often contains additives that cause it to appear mud-like.

Operation period: The period extending from the commissioning of the facility for acceptance of plutonium for disposal to the emplacement of the final load of plutonium.

Post-closure period: An indefinitely long period (hundreds of millions of years) extending from closure of the facility to a time when the emplaced plutonium and its decay products are no longer a security or safety hazard. It is expected that at least during the early years, the facility will be safeguarded and monitored.

Pre-closure period: The period covering the construction, operation and closure (decontamination and decommissioning) phases of the Deep Borehole Disposal Facility.

Pyrolysis: Heating to effect a chemical change.

Surface Processing Facility: The plutonium processing area of the Deep Borehole Facility in the receiving and processing building in the Main Facility area.

Sealant: A generic term used to refer to materials used to install low permeability seals within the borehole. The sealant materials for each of these uses are generally different and are as yet undefined although many candidate materials are being considered. The latter include grout, bentonite, bentonite/sand mixtures and clays. Currently, kaolinite clay is the preferred borehole sealant for the emplacement zone.

Transportation containers: The 2R-like Primary Containment Vessel (PCV) that contains the plutonium metal or plutonium oxide for transportation (and storage) purposes.

Transportation package: The 6M/2R-like container consisting of the 2R-like transportation container and its 6M-like external double containment assembly used for transporting the PCVs from the Disassembly & Conversion Facility to Deep Borehole Disposal Facility.

Acronyms and Abbreviations

ASLG	Atomic Safety Licensing Board
CCTV	Closed Circuit Television
CRT	Container Restraint Transport
C/S	Containment and Surveillance
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DC&I	Disassembly, Conversion & Immobilization
D&C	Disassembly & Conversion
D&D	Decontamination & Dicommissioning
DEIS	Draft Environmental Impact Statement
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	Environmental Protection And Health
FM	Fissile Material
FMDP	Fissile Material Disposition Program
HEPA	High Efficiency Particulate Air
HLW	High-Level Waste
HVAC	Heating, Ventilating and Air Conditioning
IAEA	International Atomic Energy Agency
INEL	Idaho National Engineering Laboratory
ISG	International Safeguards
kg	Kilogram (1000 grams)
km	Kilometers (1000 meters)
LA	Limited Area
LANL	Los Alamos National Laboratory
LCC	Life Cycle Cost
LLW	Low-Level Waste
LLNL	Lawrence Livermore National Laboratory
MAA	Material Access Area
MBA	Materials Balance Area
MC&A	Materials Control & Accountability
MOX	Mixed Oxides
MW	Mega Watt, Mixed Waste
NAS	National Academy of Sciences
NDA	Non-Destructive Assay
NEPA	National Environmental Protection Agency
NESHAP	National Emission Standards for Hazardous Air Pollutants
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act

OPC	Pre-Operational Costs
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety And Health Administration
PA	Protected Area
PCV	Primary Containment Vessel
PEIS	Programmatic Environmental Impact Statement
PIDAS	Perimeter Intrusion, Detection and Assessment System
PIV	Physical Inventory Verification
PPA	Property Protected Area
psia	Pounds Per Square Inch Absolute
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation And Recovery Act
ROD	Record of Decision
R&D	Research and Development
S&S	Safeguards And Security
SER	Safety Evaluation Report
SNF	Spent Nuclear Fuel
SNM	Special Nuclear Material
SQ	Significant Quantity (8 kg for Pu)
SS&C	Sand, Slag & Crucibles
SST	Safe Secure Transport
t	tonne (1,000 kg)
TRU	Transuranic Waste
UBC	Uniform Building Code
UPS	Uninterruptible Power Supply
VA	Vulnerability Assessment
WIPP	Waste Isolation Pilot Plant
ZPPR	Stainless Steel Clad Metal and Oxide Fuel